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Deliverable D4.1

Initial Description of Self-Growing Scenarios, Properties, Requirements and Envisaged Framework.

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Abstract

This Deliverable, D4.1, on "Initial Description of Self-Growing Scenarios, Properties, Requirements and Envisaged Framework" provides the steps towards realizing WP4 objectives through linking the use cases from Work Package 1 to the Self-Growing paradigm. The work, which is herein reported, initiates and elaborates on the review, refinement and evaluation of the use cases in order to identify use cases, which will get benefit from the self-growing concepts and capabilities and will provide the basis for an architectural reference model.

Executive Summary

The Cooperative and Self-growing Energy-aware Networks (CONSERN) project is an ambitious FP7 EC Specific Targeted Research Project (STREP) aiming at developing and validating a novel paradigm for dedicated, purpose-driven small scale wireless networks and systems, characterized by a service-centric evolutionary approach, introduced here as an energy-aware self-growing network.

Within this project, Work Package 4 will:

- Review scenarios and architectural decisions made by WP1 to identify use cases that will significantly benefit from applying self-growing paradigms,
- Identify and develop a suitable cognitive architecture enabling participating networks to reconfigure their topologies and optimisation goals on demand,
- Continuously review WP3 results aiming to identify and define interfaces between collaborative energy-aware control and self-growing control elements for potential integration in the architectural models,
- Elaborate on the decision making framework and its related baseline functions. These will enable describing, planning and controlling the targeted behaviour of networks participating in the process of self-growing, in a concise and scalable way,
- Identify enhancements to the framework. These will allow the learning and refinement of self-growing rules and policies by combining/filtering/enhancing knowledge obtained from the participating network nodes, networks and management entities,
- Implement the baseline functionality required to demonstrate the self-growing benefit in a proof-of-context set-up.

This Deliverable provides the steps towards realizing these objectives through linking the use cases from work package 1 to the Self-Growing paradigm, adopting the terms and definitions developed by this work package. The work which is herein reported initiates and elaborates on the review, refinement and evaluation of the use cases. It identifies use cases, which will get benefit from the self-growing concepts and capabilities and will provide the basis for an architectural reference model.

The methodology provided by work package 1 is refined to initiate the Framework definition. Such methodology defines the process for identifying the self-growing aspects in CONSERN's scenarios and use cases, the relevant parameters and next steps for a framework definition.

The WP4 related concepts are also defined in this Deliverable D4.1: the Self-growing network is described whereas the Self-Growing concept is set in relation to well-known self-x and cooperation capabilities. Such reference concepts are also described regarding their context within previous work.

The CONSERN use cases are evaluated in two directions. The first direction of use case evaluation provides an initial identification of each use case's relevance to the self-growing attribute as a system property and key benefit, as well as to functionally related to specific aspects, associated parameters, and to the key beneficiaries identified so far. The second direction of use case evaluation takes into account their relevance to the involved and/or affected industrial players' views, respecting their interest on the self-growing aspects and challenges together with an envisaged timeline and potential impact on standardization.

An initial definition for a corresponding Framework is completed, giving the outline of the envisioned progression for the transition from system properties to functional requirements and

determining the next steps required in the work towards an enabling functional architecture that will be performed in the context of work package 4.

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Acronyms

Acronym	Meaning
3GPP	3rd Generation Partnership Project
3GPP LTE	3GPP Long Term evolution
AP	Access Point
BS	Base Station
BTS	Base Transceiver Station
CEPT	European Conference of Postal and Telecommunications Administrations
COTS	Common off the Shelf
CPE	Customer Premise Equipment
CQI	Channel Quality Information
DAS	Distributed Antenna System
DSL	Digital Subscriber Line
eNB	E-UTRAN Node B
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GSM-R	Global System for Mobile Communications - Railway
IEEE	Institute of Electrical and Electronics Engineers
IEEE SCC41	IEEE Standards Coordinating Committee 41
M2M	Machine to Machine
MAC	Media access control
NE	Network Element
OAM	Operation and Maintenance
PA	Power Amplifier
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research and Development
RAT	Radio Access Technology
RNC	Radio Network Control
SNR	Signal to Noise Ratio
SON	Self-Organising Network
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WSN	Wireless Sensors Network

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1. Introduction

The CONSERN project aims at developing and validating a novel paradigm for dedicated, purpose-driven small scale wireless networks and systems characterized by a service-centric evolutionary approach introduced here as an energy-aware self-growing network.

Self-growing capabilities are enablers for a novel type of network flexibility. They allow optimising a heterogeneous collection of network nodes or sub-networks to be dedicated to a specific optimisation target (“purpose”) temporarily and on-demand. From a technical perspective this approach relies on node and network reconfigurability for achieving adaptability to multiple applications. From a complementing business perspective this approach facilitates addressing multiple niche markets / vertical markets utilizing a single line of hardware/software developments.

At this stage of work, WP4 builds upon and complements WP1 in elaborating and refining scenarios, use cases and architectural assumptions with a clear focus on enabling the development of self-growing capacities within these.

This WP4 Deliverable, D4.1, on “Initial Description of Self-Growing Scenarios, Properties, Requirements and Envisaged Framework” is structured as follows:

- Section 2 presents the concepts related to Self-growing. In this section, key concepts for the self-growing paradigm are defined, namely, the self-growing network lifecycle, the progression points, and the corresponding set of rules for the network evolution between progression points. The concepts definitions are coupled with an indicative lifecycle example for a self-growing network. Moreover, the self-growing paradigm is also related to autonomic network management and self-x and cooperative approaches,
- Section 3 describes an extended methodology for the definition of the CONSERN Self-growing Framework. This builds upon (i) the self-growing definition as a key benefit of the CONSERN project, (ii) a view on the more detailed aspects and enabling attributes, and, (iii) an evaluation of scenarios and use cases elaborated by D1.1,
- Section 4 elaborates on the use cases of D1.1 in two dimensions: (i) first, the CONSERN use cases are analysed with respect to the self-growing aspects, parameters and related benefits for the involved actors; (ii) second certain indications are provided regarding the industrial views and interests on the self-growing aspects. This section is complemented by providing additional hints on the timeline of adoption and potential impact on standardisation,
- Section 5 initiates the CONSERN Self-growing Framework by presenting the transition from System requirements to functional requirements, and the corresponding identification of the self-growing functionality. This section is completed by the identification of the requirements to the external environment. This is complementary to the architectural work, which has been initiated by the identification of functions required: the framework also considers the environment surrounding the self-growing network for development, testing, operational and management purposes.

2. Concepts Definition and State of the Art

2.1 Self-Growing concepts

In the context of the CONSERN project a self-growing network is introduced and defined as "a novel type of network composed of (heterogeneous) network nodes and sub-networks that can cooperate and utilize their reconfiguration capacity to optimize on-demand for a dedicated (temporary) purpose, also augmenting capacity by associating with additional nodes, networks, services and functions in that". Without loss of generality, a self-growing network can be assumed as a wireless network to illustrate the benefit from such paradigm. Additionally, support for node and network mobility is assumed, but is not considered a mandatory attribute for a self-growing network.

A self-growing network is considered a novel concept since it is purpose-driven, basically following a predetermined path in its functional evolution and its capacity to implement multiple purposes along this path. It is utilizing state-of-the-art concepts and enablers to realize this evolution, such as node and network reconfigurability, cognitive decision-making, and self-learning capacity. At the same time, it can respond to exceptional operating conditions by applying these concepts and enablers to define a temporary purpose satisfying demands arising from the exceptional situation. A self-growing (from "progress to maturity") network thus can be seen as a managed autonomous network guided (from "educating" or "raising") in its evolution by bounding rules. It is assumed, and has to be proven, that this approach is more suitable for low-profile, resource-limited node and network architectures compared to full autonomic network solution.

The self-growing concept incorporates both **collaborative** and **autonomic** aspects. Cooperative behaviour and problem solving is critical in the initial phase of self-growing, that is the small-scale network, as well as in the evolution to a larger scale network, able to serve different purposes and larger systems.

In contrast to existing approaches for autonomous and self-configuring / self-managing networks, a self-growing network follows some rules of evolution along its lifecycle, following, for example, a predetermined progression from purposes requiring a lower level of complexity towards purposes requiring a higher level of complexity regarding reconfiguration and collaboration capacities. Thus, a self-growing network cannot freely evolve but is restricted towards an intended purpose. Nevertheless, the degree of freedom to deviate from a planned lifecycle is a matter of the purpose of a self-growing network. In this scope, the optimal balance between the autonomic and cooperative paradigms may be different according to the purpose of the self-growing network. This will be reflected in the rules that govern the evolution of the network, favouring (and motivating) varying degrees of cooperation between the network elements. The following key elements define the self-growing attribute:

- A **lifecycle** is defined as either self-determined or pre-planned path along a sequence of **progression points** that define (potentially temporary) stable points in the evolution of a self-growing network. Progression points can be associated with stable configurations of a network potentially providing different functionalities for a certain purpose of the network. A lifecycle is defined as having one well-defined starting point and one or more potential end-points, as well as an arbitrary number of intermediate points, each of them defined by a progression point. Figure 2-1 shows a sample lifecycle comprising a sequence of progression points (*A*, *B*, *C*, *D*, *G*, *H*, *I*, *K*), transient progression points (*A.1*, *A.2*), and exceptional progression points (*E*, *E.1*, *E.2*),
- A **progression point** shall associate with a set of **attributes**. These attributes can be described each by a non-empty set of parameters. If a set of metrics is made available for these parameters, the progression point is measurable. An associated descriptive set of

factors (i.e., values of parameters) then makes a progression point well defined. Since the transition from one progression point to the next along the lifecycle is measurable in terms of parameter changes, it also implicitly describes the benefit (or cost) obtained from an evolutionary step (Figure 2-2).

Note, that the lifecycle diagram as drawn in Figure 2-1 intentionally resembles a state diagram, emphasizing that a sequence in time of progression points also may be understood as a sequence of network configuration states. In this diagram, initial, final, and exceptional states, such as those representing transient progression points, are marked by double outlined circles.

This example assumes that the self-growing network evolves from a loosely coupled collection of independent networks that federate during the initial phase of operations forming (by progressing through various states of integration) a collaborative system: sensor networks may join across an infrastructure network, and the infrastructure network gains from utilizing sensor network services. Following some (potentially iterative) optimization steps the self-growing network then keeps its configuration for regular operations. An external event might – either detected by the network or human-user-initiated – disrupt the operational phase of the network at some point in time and may cause entering a new purpose in favour of handling an incident. After returning to its regular operation the self-growing network may need to adapt its predetermined lifecycle since resources have been drained permanently (potentially by destruction of nodes). This might involve decisions – taken either by the cognitive functions of the network or by human users – to evolve towards purposes that can be realized by the remaining resources. In that, multiple options to progress may exist and the most beneficial should be selected. The lower part of Figure 2-1 correlates the example given with a lifecycle description in terms of a sequence of progression points, later revisited in subsequent descriptions from different perspectives.

How a self-growing network evolves between progression points shall be defined by suitable **rules**. Hence, the evolution of a self-growing network through its lifecycle can be described by a non-empty set of rules. Applying a rule may cause a change in attributes or parameters when commuting between progression points. The benefit of applying a certain rule is measurable, given that both the starting point and the endpoint of a transition between progression points are well-defined and are measurable. Rules might be static (e.g., known a-priori), volatile or dynamic (e.g., computed), or persistent (e.g., self-learned). Figure 2-3 provides an example for the top-level rules of the lifecycle example shown in Figure 2-1. Note that in an inference engine implementation, firing a rule in a timely manner implicitly requires an external trigger, or programmed request not shown here, except for transitional progression points which are assumed to be self-triggered.

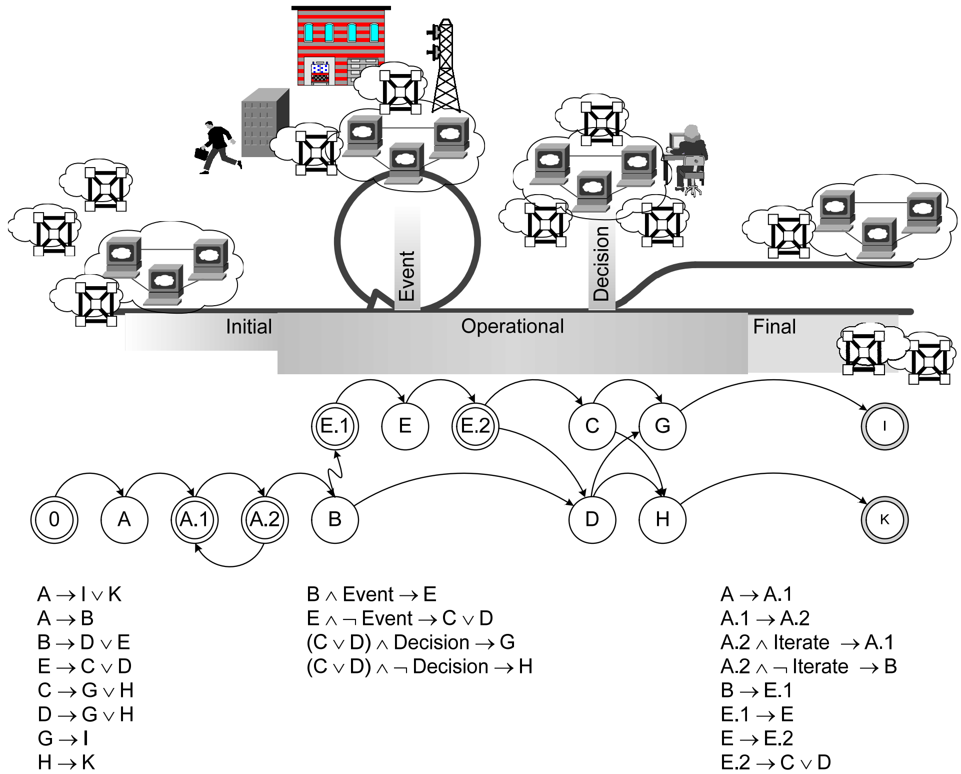


Figure 2-1: Lifecycle example for a self-growing network.

In the following, backward reasoning is (initially) assumed as a suitable mathematical inference method to describe the progression options of a self-growing network, without limiting further realization options for the CONSERN project.

For example, $B \wedge Event \rightarrow E$ here should be read as a conclusion: "if *B* and *Event* then *E*". This implies that there exists a function that realizes the reconfiguration of the network into a configuration here described by *E* if it currently is in a configuration described by *B,* and an *Event* is detected and notified by some external function out of scope for this discussion.

Consequently, the cost (or price, or net utility, depending on the mathematical method to describe the effort required) to achieve this reconfiguration is herein denoted as $\mathrm{cost}(B \wedge Event \rightarrow E)$ assuming some cost function that relies on metrics associated with parameters defined by D1.1 [12] and refined by subsequent sections of this document. This expression is synonymously used also as the cost of applying the corresponding rule, which allows comparing on the cost of certain alternatives in reconfiguring the network. Figure 2-2 illustrates how attributes and parameters correspond between different well-defined progression points, and how the benefit of changing between purposes can be measured by factorizing parameters of an attribute set and applying common metrics to parameters.

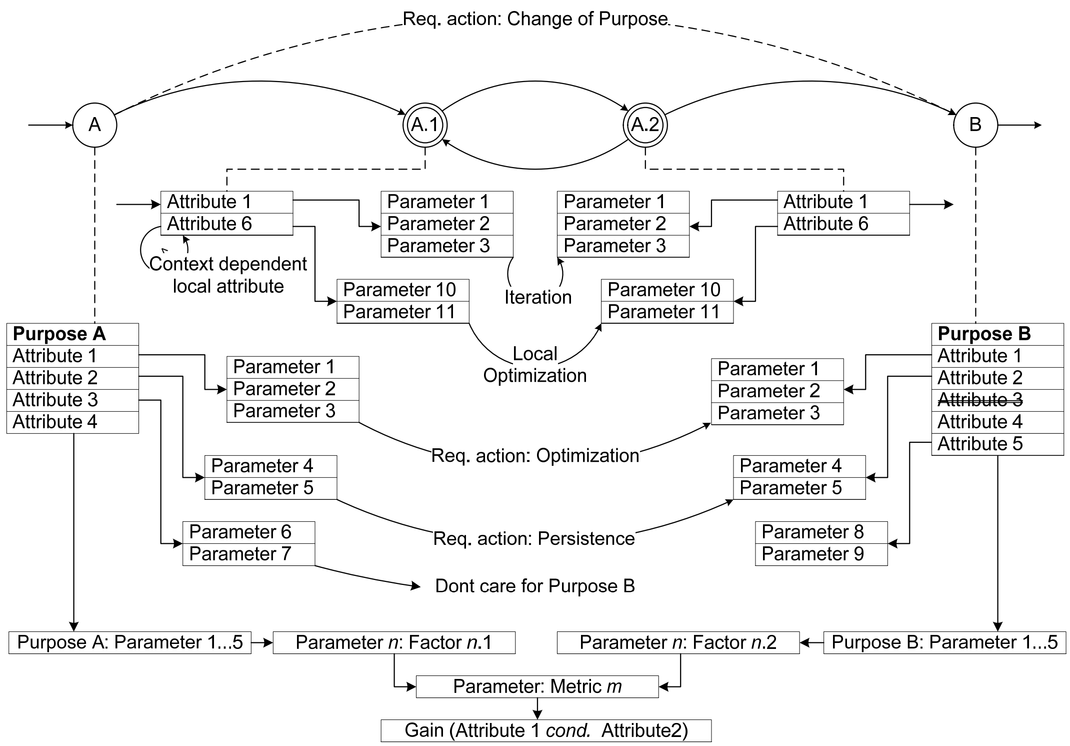
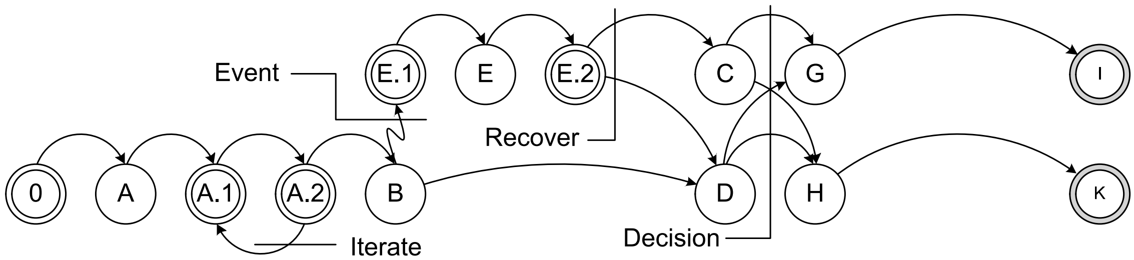


Figure 2-2: Evolution between progression points of a self-growing network and associated benefit.

The sequence of **progression points** thus defines the lifecycle of a self-growing network and the set of rules defines how it evolves through this lifecycle. In that, a well-defined and measureable progression point might associate with a dedicated **purpose** of the network. This property of a self-growing network thus allows factorizing the transition between distinct purposes of the network. Accordingly, to compare the values of metrics associated with adjacent progression points provides a way to define and measure the cost or **benefit of a transition between purposes**. The system can be extended to support mapping and evaluation between attributes with different weights using properly designed rules. Fuzzy logic modelling can potentially facilitate this process since it is well suited for capturing complex non-Boolean requirements. Metric comparison can also be interpreted as a way to evaluate a given rule set in terms of cost and benefit. Given that parameters may have multiple metrics, and given that a metric may apply to one or several parameters at a time, the approach is sufficiently flexible to enable the evaluation of the benefit of a certain network configuration at any time in the lifecycle of a self-growing network.

Clearly, the benefit of a purpose change cannot be determined for attributes that cannot be parameterized (e.g., Attribute 4 in Figure 2-2), if there exists no metric for a parameter, or if metrics exist but are not comparable between purposes. Simply speaking, a ‘before / after’ comparison and a categorization in terms of ‘is more than’ or ‘is less than’ must be possible to measure the benefit. It is not necessary that parameters must have numerical factors in this. Measurability and comparability - potentially applying transformations to achieve comparability across different metrics –are sufficient, which can be achieved by an initial classification or fuzzification step.

It must be noted here that a progression point might be **transient** (i.e., is not a well-defined purpose). Under certain conditions the set of attributes describing a progression point cannot be associated with parameters (i.e., a progression point has a non-empty set of attributes and an empty set of parameters). Although such a transient progression point might be needed as an intermediate to commute between two well-defined progression points (e.g., to describe the transition through an unstable state with, potentially, zero-time to cross), it is not wise to consider them as a valid (temporary) network configuration. This is due to the problem of determining cost or benefit of approaching or leaving a transient progression point.



$A \rightarrow I \vee K$	$A \rightarrow A.1$	$B \wedge Event \rightarrow E$
$A \rightarrow B$	$A.1 \rightarrow A.2$	$B \wedge \neg Event \rightarrow D$
$B \rightarrow D \vee E$	$B \rightarrow E.1$	$(C \vee D) \wedge Decision \rightarrow G$
$E \rightarrow C \vee D$	$E.1 \rightarrow E$	$(C \vee D) \wedge \neg Decision \rightarrow H$
$C \rightarrow G \vee H$	$E \rightarrow E.2$	$E.2 \wedge Recover \rightarrow D$
$D \rightarrow G \vee H$	$E.2 \rightarrow C \vee D$	$E.2 \wedge \neg Recover \rightarrow C$
$G \rightarrow I$		$A.2 \wedge Iterate \rightarrow A.1$
$H \rightarrow K$		$A.2 \wedge \neg Iterate \rightarrow B$

Figure 2-3: Top-level rules for the lifecycle example given in Figure 2-1 highlighting decision points.

In contrast, it may be feasible to associate a local set of attributes with a transient progression point, or with a sequence of transient progression points, which are only meaningful within a local context (cf. Figure 2-2 and progression points *A.1* and *A.2* for an example).

This can be useful to describe transient network states where optimization takes place aside the main scope (e.g., in the scope of a neighbouring network), resulting in an optimization within the main scope as a benefit for a cooperating network. Hence, the cost or benefit of progressing from a purpose to a transient progression point or vice-versa might still not be ascertainable, or might be meaningful only in the local context of the transient progression point(s). But the cost or benefit for progressing across a transient phase can be determined (cf. Figure 2-2 and Figure 2-3 with respect to the transitions between *A* and *B* as well as *B* to *E* and *E* to *C* or *D*).

On the other hand, a transient progression point can be used to commute between contexts. That is, the cost or benefit for crossing transient progression points cannot be determined (e.g., due to a lack of comparability), but entering and leaving the transient phase both might be meaningful as the cost or benefit of leaving an initial context and entering a new context, although this might be expressed in terms of different factors and metrics (and might require human interpretation).

For a number of scenarios, a lifecycle may fork towards multiple potential target purposes. This is especially true for **event-triggered progressions**, where the type of the event determines the next purpose to enter (e.g., in an emergency situation). In this, the number of optional targets must be evaluated and all of them must be assessed and judged against the objective of the evolution. For example, a near term decision might have an impact on some long-term capacity, and the relevance of being able to realize a future configuration shall be judged against a short-term benefit.

The cost of recovering from a reconfiguration necessary to handle an event in the near term has an impact on the benefit of a planned target purpose in the long-term (possibly affecting even the reachability of one of the pre-planned progression points). Resources consumed during an event then may require a different decision to optimize for the target purpose of a self-growing network. A potential approach to revise the networks lifecycle in a suitable way accordingly could be (among others) to evaluate the cost of rules applied (and to estimate the cost of rules that must be applied in the future to reach the target purpose) and to reach a new balance between cost and benefit of purposes on the path towards a target purpose. Given the lifecycle depicted in Figure 2-3, the cost of applying a rule is illustrated as $\mathrm{cost}(A \rightarrow B)$ to attain a new purpose B inferred from a purpose A under some external triggers, facts and conditions[1].

Thus, the additional cost of handling an event by the network is

$$\mathrm{cost}(Event \wedge Recover) = \mathrm{cost}(E \wedge Recover \rightarrow D) + \mathrm{cost}(B \wedge Event \rightarrow E) - \mathrm{cost}(B \wedge \neg Event \rightarrow D).$$

While the minimum cost to reach purpose G is:

$$\mathrm{cost}(B \wedge \neg Event \rightarrow D) + \mathrm{cost}(D \wedge Decision \rightarrow G).$$

The cost of approaching G and recovering first from the event-driven reconfiguration is

$$\mathrm{cost}(B \wedge Event \rightarrow E) + \mathrm{cost}(E \wedge Recover \wedge Decision \rightarrow G).$$

Omitting complete recovery and approaching a matched purpose (that probably only recovers partially since omitting D and applying C instead, which according to the rules given in Figure 2-3 is the only way to reach G without applying *Recover*) is

$$\mathrm{cost}(B \wedge Event \rightarrow E) + \mathrm{cost}(E \wedge \neg Recover \wedge Decision \rightarrow G),$$

which might be more beneficial in the long run.

Applying the evaluation method discussed above will allow comparing all potential evolutions in terms of cost and benefit on the basis of distinct attribute changes between purposes.

A self-growing network thus has the following properties:

- It coexists, collaborates or integrates – potentially in symbiosis – with collocated networks utilizing their service or geographical extent to augment network capacity,
- It relies on a focused cognitive architecture for network and node reconfiguration enabling utilization of – or potentially control of – cognitive functions (e.g., policies, rules, decision making strategies) distributed to the participating nodes and networks,
- It can switch between dedicated – potentially pre-defined – purposes (e.g. to focus on sensor network, user communications network, incident area network, etc.) on-demand. This can be a complete or partial switch, or can be focused on a certain geographical area. Switching between dedicated purposes can be triggered by a management action or an external (e.g. environmental) event.

2.2 Self-growing Enablers

The "Self-Growing" network has been defined in section 2.1 as "a novel type of network composed of (heterogeneous) network nodes and sub-networks that can cooperate and utilize their reconfiguration capacity to optimize on-demand for a dedicated (temporary) purpose, also augmenting capacity by associating with additional nodes, networks, services and functions in that". In this sense, the self-growing can be considered as building on paradigms such as:

- Autonomicity and self-x capabilities,
- Cooperation and collaboration.

In this section, the relation between the self-growing concept and mentioned paradigms will be presented.

[1] Please note that at the current level of detail for this discussion the similarities between a lifecycle and a sequence of states of the self-growing network lead to some incorrectness in wording with respect to the cost (benefit) of applying a rule and, correspondingly, the cost (benefit) of switching between network configurations. Subsequent documents will need to address this distinction more thoroughly. For the time being, this text is intended for clarification of the core topics only.

2.2.1 *Autonomic Network Management and Self-x Capabilities*

The term autonomic network management has been based on IBM's vision for autonomic computing: the system as a whole would attain a higher degree of automation than simply the sum of its self-managed parts [15][16]. Various research initiatives have been based on this motivation.

Next generation wireless network context is expected to be characterised by improvements in the management and control capabilities as well as increase in the resources that can be offered by such networks and systems. This will enable and intensify the design, development and deployment of new and novel types of applications and services.

In such a context, next generation networks and systems will have to "automatically" accommodate available services, demands and requirements, coupled with network resources in a way able to cope with constantly changing environmental conditions, service users' needs, requirements and constraints [2].

Such automation, highly related to "autonomic" capabilities, necessitates the usage of more intelligent and sophisticated technologies in order to integrate every element of the environment that would be enabled and enhanced with increased computational and storage capacities. It must be noted that **situation awareness** is a key concept for efficiently addressing such demanding management tasks and targeting enhanced operational efficiency.

Situation awareness integrates the required knowledge regarding the internal status, the telecom and physical environment with respect to a specific system/network component. Moreover, the need for situation awareness is expected to be coupled with the requirement for energy and environmental awareness. This will enable a network and/or a system not only to be managed in an optimum way but also to integrate every object in the environment under consideration which would be enabled with considerable management efficiency-related capabilities.

In order to be able to efficiently address demanding and complex management tasks **autonomic networks and systems** are expected to be able to dynamically adapt to changes in accordance with high-level business policies, objectives, requirements and constraints. Therefore, an autonomic network will be able to perform management activities based on situations it observes or senses. Such management activities and tasks will be based on context monitoring: the system continuously observes a set of parameters while trying to keep them within the desired range using a behavioural schema [2]; in such paradigms, the system administrator effort is targeted to be minimised.

The autonomic behaviour of an autonomic network or system can be further analysed as depending on a set of functionalities/capabilities, the so-called self-x capabilities; such capabilities can be enabled/deployed at node or network level.

In this context, a set of self-x capabilities has been defined in several initiatives [2], [3], [4]:

- **Self-awareness** refers to perception and cognitive reaction to an event or a condition, relevant to the node, the network or to the environment and can be considered a foundation for some of the rest of the self-x capabilities,
- **Self-management** refers mainly to the automation of Operation and Maintenance (OAM) tasks. In self-managed systems the OAM tasks are carried out by the network/system elements/components while human intervention is reflected by high level guidance to OAM; moreover, the network and its elements behaviour take into account corresponding objectives, policies, rules and constraints,
- **Self-optimisation** refers to the ability of the system to perform adjustments of its operations, attributes and parameters for achieving a targeted optimal point regarding the system performance. Such optimal points reflect the system's purposes and objectives,

- **Self-configuration** is related to the ability of a system to accommodate new operational aspects. Such aspects include newly deployed network elements and nodes, hardware, software, functional improvements and services,
- **Self-healing** is the ability of the system to respond to unplanned events which may require corrective actions. The objective is the minimisation of user impact and maintenance costs. Self-healing can be perceived as a reactive property of self-managed systems to events like failures. Through self-healing corrective actions can be initiated without disrupting system's operation by evaluating system's state,
- **Self-protection** is the ability of the system to compensate for effects of foreseen events or overcome them in terms of their impact on the operational aspects of the system. A self-protecting system should be able to detect hostile or intrusive behaviour as it occurs and take corresponding actions for protection against failures such as unauthorized use, denial-of-service, etc. in an autonomic way,
- **Self-organisation** indicates ways of collaborations of network elements and nodes based on specific management principles: absence of centralized control, adaptation to changing environment, system and network elements interacting in an autonomic way based on corresponding management policies and rules,
- **Self-locating** refers to a feature based on which the autonomic node establishes, and dynamically – periodically or upon triggering – updates a reference system to identify neighbour nodes and locate the resources required by its coordination schema [13],

At the next phase of work within WP4 the self-x features, which are listed above, will set into context with the self-growing paradigm towards further exploiting the interrelation between them.

2.2.2 *Cooperation and Collaboration*

The term cooperative communications typically refers to a system where users share and coordinate their resources to enhance the transmission quality [11]. Two features differentiate cooperative transmission schemes from conventional non-cooperative systems: 1) the use of multiple users' resources to transmit the data of a single source, and, 2) a proper combination of signals from multiple cooperating users at the destination.

More generally, collaboration denotes any type of cooperative behaviour among devices for the purpose of improving performance or increasing the chances of success in achieving an objective [19]. The main objective of collaboration usually is to improve the overall system performance in terms of throughput, energy, spectral efficiency and reliability of the collaborating wireless networks. Collaborative solutions usually exploit distributed measurements provided from each node in order to assess the overall state of the network and its environment. In the literature three types of collaboration can be distinguished:

- Cognitive radio and Cognitive networking focusing on spectrum access, allocation and sharing mechanisms ([5], [6], [7]),
- Opportunistic or delay-tolerant networking ([8]), and,
- Cooperative networking and routing focusing on relaying strategies such as fixed relaying schemes, selection relaying schemes, and incremental relaying schemes ([9], [10]).

Applicability is mostly limited to simple network structures whereas current collaboration mechanisms deal mostly with single networks or a single radio domain and mainly focus on the physical layer (minimizing interference).

2.2.3 ***Relation to Self-Growing***

This section aims at examining in what sense, level and degree the presented paradigms are related to the self-growing paradigm. As already stated, a self-growing network needs to follow some rules of evolution along its lifecycle; additionally, a self-growing network evolves towards an intended purpose. In this sense, additional and totally new network management directions need to be taken into account in order to reflect:

- The network lifecycle and the evolution along progression points,
- The purposes that can be served during a self-growing lifecycle,
- The corresponding rules for the network evolution, together with the respective actor which is liable for such rules, and,
- The environment of the network, in terms of neighbouring networks and network nodes that can be integrated in order to enable another purpose, or the embedded applications and services that can be added as a result of the new purpose that can be served.

A self-growing network or, more generally, a collection of collaborating networks can be tuned up towards a new purpose utilizing a suitable set of self-x capabilities for appropriate decision making and cross-network reconfiguration. Depending on the different self-growing types (which are introduced in section 4.5), self-growing is considered as **a scoped collection of different self-x capabilities**. A collection of collaborating networks thus becomes self-growing if it cooperatively applies its self-x capabilities for implementing a given (common) purpose. This means that a specific self-growing type can be composed by integrating **different self-x and cooperation capabilities, in different levels and in different scopes**.

- **Different level** refers to how self-growing can be composed by correlating the self-x capabilities. In this sense, some of the composing self-x capabilities contributing to the specific type can be considered as “essential”, “enabling”, or “supporting”,
- **Different scope** refers to whether the contributing self-x and cooperation capabilities are applied to a network node, a cluster of nodes (which in turn may belong to different networks) or the entire network(s).

Figure 2-4 illustrates the presented relation between the self-growing, the autonomic and the cooperative paradigms.

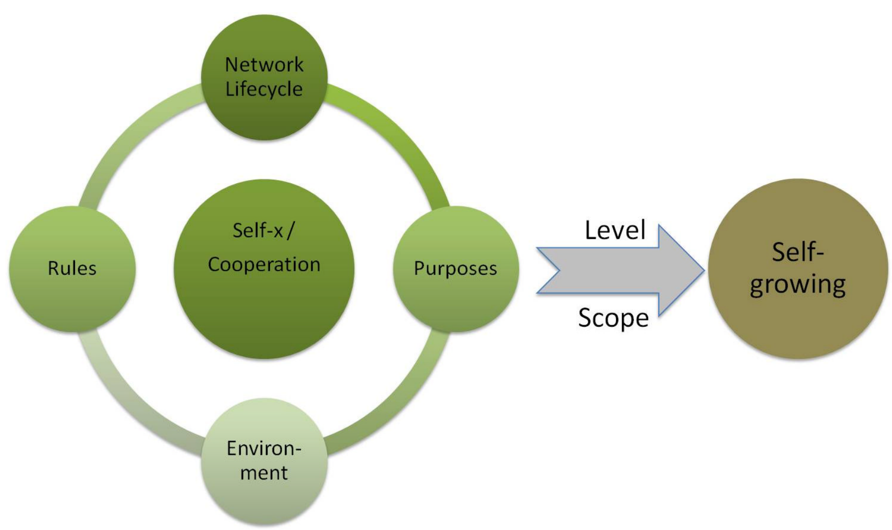


Figure 2-4: Towards the Self-Growing paradigm.

3. Extended Methodology for the Framework Definition

The methodology elaborated in CONSERN Deliverable D1.1 [12] aims at coherently deriving the system requirements as well as the use cases and scenarios from the goals or expected key benefits of the CONSERN project as described in the project proposal. Following this process allows for identifying those scenarios and use cases as well as related parameters and metrics that are best suited for illustrating a certain benefit. D1.1 concludes that individual work packages have to evaluate further on scenarios, use cases, attributes, parameters and metrics identified under their specific perspective, while considering their specific goals.

WP4 is dedicated to the self-growing aspects of CONSERN and has to identify those characteristics of CONSERN scenarios and use cases that depend on self-growing aspects and allow identifying the Self-growing as a key benefit targeted by WP4. The methodology to refine here thus is focussed on the analysis of use cases and parameter sets involved and aims to identify those use cases that are best suited to realize or visualize those key benefits.

Three potential outcomes can be expected from applying this methodology:

1. A clear definition of the key benefit "*self-growing*", which evolves from the selection of relevant scenarios and use cases provided by WP1 (where D1.1 contributes to the technical focus),
2. A clear view on the enabling attributes of a self-growing network, and the set of parameters that has to be considered for specifying functional requirements, which, in turn are required to be met in order to realize or to observe these parameters,
3. An evaluation of scenarios and use cases of D1.1 regarding their suitability, applicability and relevance to instantiate a self-growing network and to evaluate its key benefits applying the metrics which will be associated with the considered parameter set.

Subsequent sections will discuss in more detail the refined methodology applied for the purpose of WP4.

First, the identification of scenarios and use cases, concerning aspects of self-growing, and the identification of enabling attributes and associated key benefits are derived. Next, it is discussed, how specific system requirements can be identified from these, which will enable the specification of functional requirements. Finally, the approach to define the framework and to identify required modules, functions and tools is discussed. This methodology is assumed neutral with respect to any potential outcome of the various steps and it may result in either identifying a suitable set of scenarios and use cases relevant for WP4 objectives, but may also reveal that modified or different use cases not yet considered are required to achieve WP4 goals as well.

3.1 Self-growing Aspects in CONSERN's Scenarios and Use Cases

WP1 developed scenarios and use cases starting from a set of key benefits and enabling attributes without a specific target. Thus, scenarios and use cases identified are resulting from a subjective view of their creators, setting an implicit focus according to their individual interest, expertise, objectives, or concept. Hence, direct application of these use cases to an evaluation of the relevance of enabling attributes for the key benefit "self-growing" will likely produce a somewhat distorted result and will potentially not reveal all relevant parameters and metrics.

The approach taken in WP4 thus starts with selecting scenarios and use cases that have been identified by WP1 to significantly rely on enabling attributes accredited to self-growing. Next, these attributes are evaluated against other attributes accredited to the same use case to identify those use cases that potentially can identify dedicated types of self-growing (see sect. 4.5). Looking the same time on the parameters associated with these attributes is assumed to reveal the relevance of a certain use case regarding the exploitation of the self-growing as a key benefit.

As described in section 2.1, a self-growing network is described best by a number of specific properties such as its coexistence, collaboration or integration with collocated networks, utilizing distributed cognitive functions, by its purpose-driven lifecycle, or by its on-demand adaptation and optimization towards a dedicated purpose. Initially, D1.1 [12] gives a number of parameters that are associated to the ”self-growing” key benefit. In summary, these parameters are covering three main characteristics:

1. Change of the physical infrastructure (e.g., change in spatial coverage, number of nodes/networks participating),
2. Change of topology (e.g., change in connectivity, configuration),
3. Change of functionality (e.g., change in complexity, human intervention required, purposes supported).

Table 3-1 summarises the parameters from D1.1, which are associated to the self-growing attribute. It reveals that self-growing aspects are identified within most of the use cases (except 6, 12, 16, see D1.1 for a detailed definition of the use cases), but 10 out of 16 use cases consider an increasing number of nodes as a characteristic parameter. In contrast, use case 16, which covers aspects of collaboration between different wireless technologies, is not even considered for self-growing, although it is relevant for coexistence in case the number of nodes increases. Regarding enabling attributes accredited to other use cases but relying on the same shared set of parameters, it becomes clear that self-growing is strongly related to cooperativeness and reconfigurability but less dependent of parameters primarily associated with autonomicity, dependability and adaptability.

Parameters applicable to self-growing	Use Cases affected		Related enabling attributes (in order of relevance)
Change in number of purposes a network is dedicated to.	5	9, 10, 11, 15, 16	Reconfigurability
			Cooperativeness
Change in number of nodes (over network lifetime).	10	1, 2, 3, 4, 5, 9, 11, 13, 15, 16	Reconfigurability
			Cooperativeness
			Automicity, Dependability
			Adaptability
Change in network topology.	9	1, 2, 5, 8, 9, 10, 13, 14, 15	Cooperativeness, Reconfigurability
			Autonomicity
Change in network configuration.	2	1, 7	Cooperativeness
Change in set of purposes a network supports.	2	8, 9	Cooperativeness
			Reconfigurability
Amount (and complexity) of human intervention needed to add a device to the network.	3	1, 11, 15	Cooperativeness, Reconfigurability, Adaptability
Amount (and complexity) of human intervention needed to add a new purpose to the network.	2	11, 15	Reconfigurability, Adaptability

Table 3-1: Sample Parameters and use cases linked with the Self-growing Attribute.

From Table 3-1 it can be concluded that current use cases emphasize on changes of infrastructure and topology, highlighting reconfigurability and cooperativeness as the main attributes addressed by a self-growing network. In contrast, existing use cases do not sufficiently emphasize the change of functionality and do not highlight autonomicity, adaptability and dependability as enabling attributes. It is for further study if the latter is due to a lack of a suitable use case balancing these aspects, or if they are in fact of less importance for the Self growing key benefit.

3.2 Identifying relevant Parameters

The previous step has identified the main enabling attributes of a self-growing network. In order to identify the functional requirements and related requirements of the framework, it is needed to identify also relevant associated parameters. This will provide a sufficiently large set of parameters to be considered for defining the functional requirements within the framework. Additionally, this step associates self-growing enablers (repeatedly) with other key benefits in scope of the CONSERN project (i.e., energy awareness and situation awareness), but introduces a new perspective which is independent from the initial use cases. It is assumed that this step will enable to generate “synthetic” use cases that are more suitable to showcase specific attributes of a self-growing network compared to use cases already defined by D1.1.

D1.1 provides an initial list of parameters associated with the enabling attributes of the key benefit. Parameters associated with both the self-growing attribute as well as with related enabling attributes must be considered based on the relevance of the corresponding attributes.

3.3 Defining the Framework

In principle, a **framework** may summarize a set of functions and/or components within a system including the interrelations between the mentioned concepts. A framework is generally more prescriptive than architecture. A more detailed definition is provided in section 5.

From previous steps, a list of parameters ordered by their relevance in contributing to the self-growing key benefit has been identified (Table 3-1). For an initial step in specifying the CONSERN Self-Growing Framework, theses parameters must be evaluated against a number of objectives in order, for example, to estimate the degree of a parameter’s applicability, measurability, etc. A non-exhaustive list is given below and must be completed by subsequent WP4 activities:

- Which type of function is required to implement the control of this parameter?
- Which metrics apply to the parameter?
- Which type of function is required to measure or monitor this parameter?
- Which parameters are closely related (in terms of functional similarity) and might be evaluated or realized by functions collocated to each other (e.g. functions realized by different software or hardware modules on a common platform)?
- For example, RF measurement and GPS positioning for a spectrum sensor: different functions, different purposes, different parameters but collocated due to the requirement "to get the position of an RF sensor"?
- What “real world” physical parameters are associated with parameters considered above and how can these parameters be generated or measured?

The result of this evaluation is specifying the functional components of the framework, which in total define part of the functional architecture of a self-growing network. It is assumed that having the relevance of parameters and their association with other key benefits can be utilized to define sub-sets within the functional architecture able to realize different types of self-growing. Additionally, this evaluation should allow defining the environment in which a self-growing network should exist in order to gain from its capacity, as well as a testing environment for the functional model.

A shortcoming of this approach is in its lack to evaluate the interaction of functions of the framework. It thus is not able to formalize the full reference architecture. This step requires a suitable use case to be defined first, which will be in the scope of subsequent WP4 activities.

4. Use Cases Refinement

4.1 Introduction

As discussed in section 3.1, a number of uses cases given in [12] can be associated with the self-growing attribute of a network (cf. Table 3-1). In this section use case evaluation and pre-selection is performed in order to highlight the relation of the CONSERN use cases to self-growing concepts. In this sense, such analysis is performed under two perspectives.

In the first, the selection of use cases is ordered by relevance elaborating on those use cases directly associated with attributes and relying on parameters accredited to self-growing.

Under the second perspective, the order of relevance is derived from an evaluation with respect to industrial relevance and estimated timeline of deployment.

The approach is intended to avoid excluding use cases in an early stage of analysis that may be of practical relevance in contributing to a later stage of the framework definition or for subsequent business-oriented evaluations complementing the technology oriented analysis performed by this work package.

As a next step, the use cases will be further evaluated in terms of their association not only with the self-growing attribute and related parameters but also with enabling attributes related to self-growing in a similar context (i.e., partially relying on parameters accredited to enabling attributes of self-growing, such as reconfigurabiliy). Such evaluation will also be based on the exploitation of the correlation between the different type of attributes (key benefits, enabling attributes, and performance attributes).

In the end of this section, the relevance of the CONSERN use cases to the Self-Growing attribute is summarised.

4.2 Self-growing in D1.1 Use Cases - an Evaluation

Starting from the set of use cases identified in Deliverable 1.1, it is meaningful to assess these use cases in terms of their relation with WP4. Since self-growing capabilities and mechanisms constitute the key property of WP4, an evaluation of the use cases in the context of this WP should focus on identifying and studying the different forms of self-growing capabilities, as well as the related attributes, metrics and their parameters. In order to perform this evaluation, different aspects of self-growing mechanisms can be studied according to the purpose of each use case. In this direction, self-growing capabilities are initially assessed in terms of the scalability and evolvability attributes of the system as better reflecting the key parameters, which are related to the self-growing attribute:

- **Scalability** is the ability of a system to accommodate changes in transaction volume without major changes to the system and to continue to function well when it is changed in size or volume. In this sense, scalability is closely connected to the change of physical infrastructure and topology,
- **Evolvability** is the ability of a system to evolve its structure, scope, size or any other characteristic in order to meet the users' needs in an autonomic way. In this sense, evolvability is connected to the change of provided functionality.

In relation to the attributes and parameters identified in D1.1 that are related to the self-growing attribute, **scalability** is closely connected to the number of network nodes, network configuration, network topology, degree of coexistence, as well as the amount of human effort required to add new devices in the network. On the other hand, **evolvability** is connected to the changes in number and/or set of purposes a network is dedicated to, as well as the amount of human effort required to add a new purpose.

Another classification of the use cases enabling to assess the impact of the self-growing concept relates to the potential beneficiaries from an introduction of self-growing mechanisms.

In this direction, in the following tables the different aspects of self-growing mechanisms per use case and the corresponding key beneficiaries from the self-growing application are identified.

Use case	**UC-01/OTE: Energy Optimisation in a moving vehicle with capacity and coverage limits**
Item	***Comment***
Short Description	In an environment where there is demand for increasing capacity, several WiMAX BTS's are located and sensors enable controlling the network elements' (NEs) operation in order to achieve energy efficiency under coverage constraints. For example, in a moving train, by using a relay established on its top and WiMAX CPEs inside, capacity and coverage optimization can be achieved along with expandability. This enables the network operator to identify which is the optimum network configuration regarding users' needs in the corresponding area.
Aspects of self-growing concept	Scalability aspects in terms of the number of WiMAX BTSs and relays, the degree of their co-existence and how difficult it is to add new devices (in terms of complexity and human effort). In a self-growing approach, a relaying node may decide autonomously to reconfigure to establish a mobile network trunking to the operators BTS rather than acting as a repeater depending on the number of users involved.
Parameters related to self-growing	Change in network configuration, Change in number of nodes, Change in degree of coexistence
Key beneficiaries	Network Operator – provision of network services in demanding contexts, Network Operator - efficient network management, User – Improved QoS provision, Platform Module Developer – CONSERN module.

Table 4-1: Self-Growing aspects in UC-01/OTE.

Use case	**UC-02/NKUA: Energy Optimisation in an Office environment under coverage constraints**
Item	***Comment***
Short Description	In a dense environment where several Wifi APs and UMTS femto cells are co-located, the use of sensors enables controlling the network elements' operation in order to achieve energy efficiency under coverage constraints. This can be based for example on keeping specific network elements operational only when needed. This enables the network operator to identify which is the optimum network configuration regarding the users' needs in the corresponding area.
Aspects of self-growing concept	Self-growing capabilities that appear in this use case are related mainly to the number of network nodes, their topology and configuration, as well as

	their degree of co-existence. Certain nodes or networks may autonomously decide to collaborate to establish a dedicated administrative domain sharing resources and services.
Parameters related to self-growing	Change in number of nodes, Change in network configuration, Change in degree of coexistence
Key beneficiaries	Network Operator – efficient capacity usage and service provision, Network Operator - efficient resource usage,

Table 4-2: Self-Growing aspects in UC-02/NKUA.

Use case	**UC-03/NKUA: Energy Optimisation for Self-Growing Office environment under coverage and capacity constraints**
Item	***Comment***
Short Description	In a dense environment where several Wifi APs and UMTS femto cells are co-located, the use of sensors enables controlling the network elements' operation in order to achieve energy efficiency under coverage and capacity constraints. This can be based for example on keeping specific network elements operational only when needed. This use case features the self-growing network paradigm through gradually integrating different WSNs in the area for serving coverage, increased capacity and power consumption demands. Moreover, this enables the network operator to identify which is the optimum network configuration regarding the users' needs in the corresponding area.
Aspects of self-growing concept	This use case presents both the scalability and evolvability aspects of self-growing. Specifically, the former is related to the number of network elements, network configuration and co-existence, while the latter is related the number of purposes that specific network elements or even the network as a whole can serve. A self-growing network may decide autonomously to consider peak load times as an exceptional operational mode and may then reconfigure to serve temporary demands by providing additional access capacity balancing energy consumption and interference on a different level compared to its normal operation.
Parameters related to self-growing	Change in number of purposes a network is dedicated to Change in set of purposes a network supports Amount (and complexity) of human intervention needed to add a device to the network Amount (and complexity) of human intervention needed to add a new purpose to the network Change in network configuration Change in degree of coexistence
Key beneficiaries	Network Operator – efficient capacity usage and service provision,

	Network Operator - efficient resource usage, WSN Provider – increased data provision to Network Provider.

Table 4-3: Self-Growing aspects in UC-03/NKUA.

Use case	**UC-04-IFX: Network reconfiguration following the introduction of new nodes**
Item	***Comment***
Short Description	In a dense (home/office) environment there are a multitude of various APs / BSs deployed, building on various RATs. Some of those are supposed to be accessible (typically owned) by the concerned entity, some are partly/fully out if its control, e.g. those network nodes belonging to a neighbour, etc. In the framework of the self-growing paradigm, additional network nodes are constantly added. The subsequent reconfiguration of the network needs to be performed autonomously, i.e. without any user interaction. In particular, the following key steps need to be performed: i) identification of network congestion (e.g., which network nodes introduce interference by accessing to identical bands, which nodes are overloaded, etc.) and identification of network nodes being accessible for reconfiguration (including level of accessibility); ii) determination of optimum network configuration by reconfiguring some/all of the accessible nodes; iii) seamless execution of the reconfiguration, i.e. the user experience should remain as little impacted as possible.
Aspects of self-growing concept	This use case emphasizes on the scalability aspect of self-growing capabilities and specifically the number of APs/ BSs and the autonomic introduction of new nodes, network configuration and seamless reconfiguration, as well as the co-existence of the different networks/RATs. Regular operations of a self-growing network may define the corresponding purpose as “being able to accept a growth both in geographical extent and number of fixed and mobile nodes”. As long as energy and coexistence constraints can be satisfied by the means available within the scope of this purpose neither exception handling nor reconfiguration towards another purpose is needed. If the purpose cannot be satisfied any longer due to exceptional growth a purpose change takes place to enable new means to handle the demand.
Parameters related to self-growing	Amount (and complexity) of human intervention needed to add a device to the network Change in number of nodes (over network lifetime) Change in network configuration Change in degree of coexistence
Key beneficiaries	Network Operator – efficient network management (reconfiguration).

Table 4-4: Self-Growing aspects in UC-04/IFX.

Use case	**UC-05/HWSE: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks**
Item	***Comment***
Short Description	Cellular systems are dimensioned for peak hour traffic, thus they are over-

	provisioned, by still being active, during low traffic periods. By reducing the number of active resources when traffic is low, significant power saving can be achieved. The decision to gradually add or remove resources (in a switch on/off manner) is based on cooperative decisions and joint actions between the mobile users and the base stations (BSs) of the network. Depending on the user location, distribution and topology of the network, switching on/off certain resources can cause the corresponding adaptation of parameter settings in neighbouring cells, e.g. transmit power, antenna tilt and radiation pattern. Such network re-configuration might be necessary in order to cope with QoS degradation and coverage and capacity loss.
Aspects of self-growing concept	Self-growing mechanisms related to number of nodes and number of active nodes, network topology, configuration and co-existence. A self-growing network may respond to a change in traffic load and number of nodes by reconfiguring, which can be seen as a change of purpose between several predefined purposes utilizing different self-optimization goals. Whenever the benefit of changing a purpose outperforms the cost of reconfiguring the network, evolvement towards a different purpose takes place either resulting in energy savings or in providing additional functions utilizing spare resources.
Parameters related to self-growing	Change in number of nodes Change in network topology Change in network configuration Change in degree of coexistence
Key beneficiaries	Network Operator – efficient service provision, Network Operator – reasonable network resources management.

Table 4-5: Self-Growing aspects in UC-05/HWSE.

Use case	**UC-06/HWSE: Cooperative DAS nodes configuration**
Item	***Comment***
Short Description	In a dense environment, such as home/office and hotspot in urban area, the area is covered by several independently running cells. In each cell, multiple antenna nodes are uniformly distributed within the area and they are controlled by a central processor. In order to provide high capacity and energy efficiency, the on/off and signals transmitted by the cooperative DAS nodes in a DAS cell are centrally configured according to both long term cell-specific statistics or short term terminal-specific information. The transmission of cooperative DAS nodes controlled by different central processors can be coordinated by distributed methods.
Aspects of self-growing concept	Self-growing related to changes in the number of antennas, as well as the network configuration and co-existence. A self-growing network may autonomously decide either to handle capacity and coexistence demands by self-optimization of the antennae sub-systems or by evading into an exceptional purpose that allows interaction with an operator to enhance the performance achieved through manual modification of the antennae sub-systems. This purpose may involve test

	functions that allow simulating or estimating the impact of newly placed antennas to the self-optimization behaviour of the whole system operating for its regular purpose.
Parameters related to self-growing	Change in network configuration, Change in degree of coexistence
Key beneficiaries	Network Operator – reasonable network infrastructure and resources management.

Table 4-6: Self-Growing aspects in UC-06/HWSE.

Use case	**UC-07/HWSE: Cooperative relay for energy efficiency**
Item	***Comment***
Short Description	Due to the cubic channel fading between BSs and mobiles in Infra-structure Networks, relay nodes reduce the distance to mobiles, which means relay node consumes less power compared to direct BS transmission in order to achieve same SNR level. Since the traffic in certain area may be dynamically changed, relay nodes (including relay stations and UE relay) can cooperate with each other to provide high data rate service for heavy traffic conditions, while the relay node in low traffic area can switch off or reduce its power to save energy. This use case corresponds to Infra-structure Networks scenario where criteria and actions for cooperative relay schemes for system power consumption reduction and system capacity improvement is addressed. The relay nodes collect and learn about the network topology, channel information, traffic load, service features and neighbour nodes statistics, based on learned information and predefined policy, relay nodes make cooperative decisions, cooperate with other nodes, use network coding enhanced cooperative scheme to provide high system throughput and energy efficiency. Relay nodes may provide content-oriented traffic offloading scheme for load balancing.
Aspects of self-growing concept	Self-growing aspects related to the number of nodes and number of relays, complexity for adding new nodes, changes in network topology and configuration. In a self-growing approach, a relaying node may decide autonomously to reconfigure based on a cooperative decision regarding the load distribution among nodes, repeaters and BSs. While the regular purpose limits the means to respond to a change in demands, a purpose switch may be suitable to release some of the operational constraints set by the regular purpose (e.g., interference, spectrum usage or energy constraints) achieving stable operations with changed focus objectives for self-optimization.
Parameters related to self-growing	Change in degree of coexistence Change in network topology Change in network configuration Amount (and complexity) of human intervention needed to add a device to the network
Key beneficiaries	Network Operator – Improved capacity.

Table 4-7: Self-Growing aspects in UC-07/HWSE.

Use case	**UC-08/Fraunhofer: Energy-aware end-to-end delay optimization**
Item	***Comment***
Short Description	Sensor nodes are deployed in a given environment partially covered by a second type of network, e.g. IEEE 802.11 WLAN. During their lifetime of the sensor network, a change in its purpose occurs: in addition to existing functionality, nodes have to report on delay sensitive data to a data sink. For such, the sensor network has to be reconfigured: the routing of messages through the sensor node (multi-hop communication) and the sleep cycle of the sensor nodes has to be adjusted to meet the delay constraints. As a result, the purpose change is achieved but the network's lifetime is degraded. A cognitive decision entity uses this information to evaluate if a potential synergy of the partially deployed WLAN network with the sensor network can enable the new purpose at better energy cost. Integrating both networks enables additional routes from the sensor to the data sink. Those routes may have different properties in terms of delay and the resulting energy consumption of involved sensor nodes for using them. Having this information, the cognitive engine can dynamically decide on a purpose-driven configuration and on the symbiotic integration of the two networks.
Aspects of self-growing concept	Self-growing is supported in both the scalability and evolvability aspects. Specifically, scalability is addressed in terms of changes in network topology and degree of co-existence. Evolvability is addressed in terms of changes in the set/number of purposes a network supports. In case of an externally requested/initiated purpose change a self-growing network may autonomously decide to utilize coexisting neighbouring nodes to achieve the goals set by its new purpose, or may decide which out of a set of potentially attainable purposes can be achieved most beneficially given the availability of collaborating nodes within its operational environment and context.
Parameters related to self-growing	Amount (and complexity) of human intervention needed to add a new purpose to the network Change in network topology Change in degree of coexistence Change in set of purposes a network supports.
Key beneficiaries	Network Operator – multi-purpose network operation, WSN Operator – Information provision to communication networks in the vicinity.

Table 4-8: Self-Growing aspects in UC-08/Fraunhofer.

Use case	**UC-09/Fraunhofer: Purpose-driven network reconfiguration during an emergency situation**
Item	***Comment***
Short Description	Sensor nodes forming an ad-hoc network are deployed in a given

	environment partially covered by a second type of network providing centralized, single-hop backbone access, e.g. IEEE 802.11 WLAN. Both networks had gone through the self-growing phase having resulted in an integrated, symbiotic network under the control of cognitive decision entities. Under normal operation, the sensor network provides sensing information (e.g. temperature in various locations of a building) at low duty cycles; the network is optimized for long network lifetime accepting higher delays in the acquisition of sensing information. An incident situation occurs (e.g. a fire in parts of a building). As a result, parts of the existing sensor node infrastructure are destroyed. Also, as a result of the incident situation, the metric driving the network configuration changes and the network has to fulfil a new purpose: an extremely long lifetime of the network is less important but sensing information has to be delivered in a timely manner. Besides, the sensor nodes have to additionally detect persons in the building or even track the movement of emergency responders. For such, coverage in specific areas has to be ensured. Cognitive decision engines detect this situation and decide on a network reconfiguration, possibly including the symbiotic effects of the integrated WLAN network to cope with the incident situation and its associated change in purpose.
Aspects of self-growing concept	Both evolvability and scalability notions are addressed. Specifically, in the first aspect, the use case considers changes in the number and sets of purposes that are supported by the network. In the second aspect changes in the number of nodes and network topology are considered. A self-growing network may decide autonomously if within its resource constraints (potentially severely restricted by the event) a reconfiguration and involvement of collocated infrastructure may serve the goals of a new purpose. This might involve several transient purposes until a configuration is found balancing the purpose's goals, own resource consumption and resource consumption from collaborating infrastructure. This may include decisions that a certain purpose cannot be attained without human intervention or without irrevocably consuming all available resources in the course of configuring towards a new purpose (e.g., in terms of battery lifetime).
Parameters related to self-growing	Change in network topology Change in number of nodes (over network lifetime) Change in set of purposes a network supports Change in number of purposes a network is dedicated to.
Key beneficiaries	Network Operator – multi-purpose network operation, WSN Operator – Information provision to communication networks in the vicinity.

Table 4-9: Self-Growing aspects in UC-09/Fraunhofer.

Use case	***UC-10/Fraunhofer: Cognitive Coexistence and self-growing for white space operation***
Item	***Comment***

Short Description	This use cases focuses on a locally deployed access point operating in white spaces in order to form a WLAN providing access to a small (company) network. During its lifetime, the capabilities of the device dynamically grow from an operation without coexistence to a fully coexisting operation mode with other white space devices deployed in the surrounding. In a second phase, the self-growing of the network, the purpose of the deployed network elements grows from only supporting nomadic mobility to additionally supporting seamless mobility for mobile users. In particular, this is achieved in various ways: A cognitive decision engine achieves separation in (used) spectrum by intelligently assigning valid spectrum portfolios to devices. Hereby, the engine learns about the requirements of each device and intelligently considers a dynamic adaptation of assigned spectrum per node/network. This allows each network to adapt its purpose according to users' needs (e.g. adding low latency low bandwidth communication for surveillance purposes to existing high bandwidth but long delay services). At the same time, the cognitive engine learns about devices having coexistence issues (and hence are candidates for being in communication range of each other). Hence, the rules of the decision engine at each device are updated to allow a technology specific detection of other (heterogeneous) devices in communication range. Where applicable, the cognitive decision engines may decide to trigger a reconfiguration of devices enabling direct communication among existing networks. This self-growing phase enables additional services. First, direct (or multi-hop) wireless links among deployed devices allow to distribute among several low-bandwidth wired connections (e.g. DSL lines) the traffic going to and coming-in from the Internet. This enables high-throughput communication and allows fully exploiting the capacity of the wireless communication medium. Second, existing homogeneous network elements originally not in communications range of each other and support nomadic mobility of the end-user. The self-growing process integrates several heterogeneous network elements into one access network providing continuous radio coverage to the end-user thereby enabling seamless mobile usage.
Aspects of self-growing concept	Addresses self-growing capabilities related to evolvability (in particular changes in the number of purposes provided by a single network through reconfiguration of nodes to enable new purpose) as well as scalability (change in network topology, number and node locations). In its long-term lifecycle a self-growing network may focus on coexistence with incumbent spectrum users and other white space users. In handling an incident / exceptional situation a self-growing network may reconfigure potentially disregarding regulatory constraints to provide bandwidth or coverage as demanded by first responders, for example. In that a self-growing network operating in white spaces provides additional reconfiguration options both beneficial for own operation as well as for providing services to collocated networks, gaining from flexibility in spectrum usage.
Parameters related to self-growing	Change in network topology Change in network configuration

	Change in number of purposes a network is dedicated to
Key beneficiaries	Network Operator – multi-purpose network operation.

Table 4-10: Self-Growing aspects in UC-10/Fraunhofer.

Use case	**UC-11/IBBT: Energy optimization of co-located wireless networks in a home/office environment**
Item	***Comment***
Short Description	In the future there will be a high number of networks that are active in and around home/office environments. Hence, the number of mobile and wireless devices and networks is increasing, inevitably leading to an increase in the density of co-located wireless devices. Today the capacity of wireless networks is generally increased by adding wireless infrastructure (more access points, more sensor networks...). More important is the coordination and cooperation between co-located wireless networks & devices, in order to avoid undesired interference. Today, this leads to unnecessary energy wastage and further involves a lot of human interventions and manual calibrations/configurations, resulting in high commissioning and maintenance costs. Although more and more networks tend to incorporate self-organizing and self-maintenance properties, autonomy is still limited within network boundaries. Autonomous solutions may even fail, because the independent co-located wireless networks may jeopardize each other. A setting, which is beneficial for one network, may turn out to have the reverse effect for other co-located networks. Through advanced inter-network cooperation (involving negotiations and joint decisions for minimizing interference and energy consumption), this use case aims to offer autonomous solutions for coordinating or even merging (independent) co-located wireless networks, enabling more efficient service delivery and an extended reach of service usage. Such solutions will not only improve energy efficiency, but also user satisfaction. In addition deployment, commissioning and maintenance cost will be reduced.
Aspects of self-growing concept	Self-growing mechanisms related to changes in the number of purposes a network is dedicated to (evolvability) as well as changes in the number of nodes and the amount (and complexity) of human intervention needed to add a device to the network (scalability). Regular operations of a self-growing network may define the corresponding purpose as “being able to accept a growth both in geographical extent and number of fixed and mobile nodes”. As long as energy and coexistence constraints can be satisfied by the means available within the scope of this purpose neither exception handling nor reconfiguration towards another purpose is needed. If the purpose cannot be satisfied any longer due to exceptional growth a purpose change may take place in order to handle the increasing demand either temporarily or permanently by enabling new means to control operation and new self-optimization and self-organization strategies through entering a different purpose, potentially relaxing some of the earlier constraints.
Parameters related to self-growing	Change in number of purposes a network is dedicated to

	Amount (and complexity) of human intervention needed to add a new purpose to the network Change in number of nodes
Key beneficiaries	Network Operator – multi-purpose network operation, Network Operator – improved energy-aware network management User – improved QoE.

Table 4-11: Self-Growing aspects in UC-11/IBBT.

Use case	***UC-12/IMEC: Self-adaptation of a reconfigurable wireless terminal***
Item	***Comment***
Short Description	To meet the link budget constraints under these challenging conditions, systems need to be configured with the worst case configuration in each part of the system. Some well-known examples are: • Maximum output power for the PA, • Highest modulation and code rate for the physical layer, • Always on at the MAC layer. Next to the above considered parameters, reconfigurable network elements typically provide a broad range of low-level tuning knobs to adapt the operation of the system. Configuring those parameters at runtime, taking into account instantaneous operating conditions, can result in significant energy savings. The self-adapting network element collects information about its application requirements, channel conditions, and learns about the collocated network in order to adapt its operating parameters to save energy. Depending on a predefined policy, the optimization objective of the self-adaptation is the local energy only or a global energy cost of the network or group of collocated networks.
Aspects of self-growing concept	No self-growing concepts (based on use case's highlighted attributes in D1.1) A self-growing network may utilize independent terminal self-configuration capacity to optimize its operation within its current operating purpose given that cognitive decision making on the network and terminal level can collaborate accordingly. In white space operations, for example, coexistence between a reconfigurable terminal and an incumbent may be handled by the terminal, while spectrum management and interoperability may be handled by the network, enabling cooperation with collocated network infrastructures.
Parameters related to self-growing	No self-growing concepts (based on use case's observed parameters in D1.1)
Key beneficiaries	--

Table 4-12: Self-Growing aspects in UC-12/IMEC.

Use case	***UC-13/TREL: Home Monitoring Energy Optimization***
Item	***Comment***
Short Description	A smart home environment has a number of sensor and actuator nodes,

	with a wide variety of functions and capabilities. It includes control of all smart metering, lighting and heating devices and could include in the order of a hundred independent nodes. A gateway central node controls the collection and reporting of the data. The system grows with more devices added and more existing devices are placed under control of the energy management system. For efficiency and energy consumption reasons the system moves from a centralized polled system into a more decentralized one where collected data is summarized at intermediate points, and control is delegated to selected devices. The system needs to make the transition gradually to permit centralized and decentralized systems to cooperate.
Aspects of self-growing concept	Self-growing aspects related to changes in network topology, as well as alternative configurations for current operating conditions. When deployed in a home environment a self-growing network may benefit from a long-term lifecycle, its multi-purpose capacity and its capacity to change between different purposes. Aside home monitoring as a main purpose, additionally available purposes might be optimized for certain living conditions, for example, enabling assisted living functions when residents are present and surveillance functions when residents are off. Dedicated emergency purposes and learning / adaptation capacities may increase versatile use. In any case, energy efficiency, dependability, interoperability, ease of use, and cost efficiency are most important for wide acceptance in this application area.
Parameters related to self-growing	Change in network topology Alternative configurations for current operating conditions
Key beneficiaries	Home owner – cost saving related to energy optimisation.

Table 4-13: Self-Growing aspects in UC-13/TREL.

Use case	***UC-14/TREL: Cooperation Enablers in Home Gateway Environments***
Item	***Comment***
Short Description	In the home network scenario, multiple devices trying to access the same frequency resources is extremely common due to the explosion of networked devices within the home. In femtocells, even though communication is through licensed bands, due to the proximity of femtocells in dense areas, interference is still a very real problem, which may in particular affect subscribers of macro cells being close to femtocell-dense areas. Interference within home networks comes at the cost of energy efficiency and reliability. An effective way of curtailing interference is to ensure that each device keeps its transmission power low. However, in circumstances where devices are far apart, this may not be possible. As a result, techniques such as cooperative transmission may be required to enhance the quality and reliability of communication between devices. Additionally, energy efficiency is also crucial to many mobile devices as it improves the battery life of the devices. In home networks, where mesh network is the common network topology, techniques such as physical layer network coding can be further applied to improve energy efficiency. The home gateway is also equipped with multiple access technologies such as mobile radio network, wireless LAN, home automation (mesh) network, and so on. Including this heterogeneous set-up in our considerations will

	enable further cooperation, relaying and environmental-awareness capabilities.
Aspects of self-growing concept	No self-growing concepts (based on use case's highlighted attributes in D1.1) A self-growing network may utilize independent gateway self-configuration capacity to optimize its operation within its current operating purpose given that cognitive decision making on the network and gateway level can collaborate accordingly. Neighbouring gateways may cooperate for coexistence and may collaborate in sharing resources if, for example, associated with the same provider (e.g., for public / private use).
Parameters related to self-growing	No self-growing concepts (based on use case's observed parameters in D1.1)
Key beneficiaries	--

Table 4-14: Self-Growing aspects in UC-14/TREL.

Use case	***UC-15/Fraunhofer: Dynamic Meeting Setup Flexible Office/Building Environments***
Item	***Comment***
Short Description	One company has reserved a public meeting room to hold a meeting with a few project partners. Some partners are from a branch office, some are from an external company, and some from a public authority. Thus, the various people in the meeting have different roles and different rights for using surrounding communication technologies or accessing resources of the other stakeholders (e.g. internal project files, public documents, source code etc.). Furthermore, an initial network access is provided by the owner of the public meeting room, but is temporary owned by the meeting organization company. The result is a quite complex and dynamically changing networking setup with several roles, rights, restrictions, and policies (e.g. some people use Wi-Fi, some LTE/femto, and some can communicate directly over Bluetooth).
Aspects of self-growing concept	Addresses self-growing capabilities related to evolvability (in particular changes in the number of purposes that the network is dedicated to) as well as scalability (change in network topology). A self-growing network may decide to choose a dedicated purpose for each type of meeting (type of use) in order to satisfy varying user demands. If a suitable learning method is made available a self-growing network may detect automatically the type of meeting from its usage parameters and may consequently change to a matching purpose. Dedicated purposes for learning and dedicated operation may apply to evolve and maintain a knowledge base for different types of use.
Parameters related to self-growing	Change in network topology Number of self-growing enabling nodes per service area Change in number of purposes a network is dedicated to
Key beneficiaries	User - enhanced QoS and QoE

	Enterprise, Meeting Organisation Company: cost saving on service provision and network management.

Table 4-15: Self-Growing aspects in UC-15/Fraunhofer.

Use case	***UC-16/Fraunhofer: Collaboration of Different Technologies***
Item	***Comment***
Short Description	A printing and advertising company has expanded and requires three additional offices and a new printing room for high end printing devices. Thanks to the flexible building design it is more or less simple to move some walls and change the furniture. The building owner that leases the rooms uses a powerline based metering system (e.g. digital STROM or others) to logically separate the power grid used by a company for calculating the energy costs separately. Moreover, the printing company uses additional own wireless metering systems (e.g. ZigBee) for the printing devices to exactly calculate the energy costs for each printout. Alternatively, energy costs for the next printouts can be predicted based on the observation of further printings and an optimal printing time slot can be selected where the energy providers offer lower prices. This scenario is an example for the interconnection of different types of communication technologies (powerline, wireless sensors, IP based backbone etc.) to build a virtual, self-growing network that allows to collectively achieving a goal.
Aspects of self-growing concept	Self-growing mechanisms related to changes in the number of purposes a network is dedicated to (evolvability) as well as changes in the number of nodes (scalability). A self-growing network may follow its long-term lifecycle changing purposes whenever significant changes in type of network use or configuration takes places. Additionally, temporary reconfigurations may be satisfied by interrupting the regular purpose in case of increased traffic load, additional monitoring and control demands for the existing machinery (e.g., queuing mass print jobs to periods of lower energy prices).
Parameters related to self-growing	Change in number of purposes a network is dedicated to, Change in number of nodes (over network lifetime), Change in network topology, Change in degree of coexistence (number of nodes and/or networks which are coexisting), Number of self-growing enabling nodes per service area
Key beneficiaries	Company - cost saving Company – enhanced value proposition.

Table 4-16: Self-Growing aspects in UC-16/Fraunhofer.

4.3 Self-Growing Use Cases selection and processing

Beyond technical aspects, the selection of use cases for further study and processing needs to be performed based on a close consideration of industrial requirements. In particular, it is intended to select a set of several use cases representing self-growing concepts and solutions which target a short-term, low-risk, limited potential (in terms of self-growing entities, network nodes, infrastructure elements, etc. to be sold, their unit price, etc.) up to long-term, high-risk, high potential application. Such an approach in particular has the advantage that industrial players typically prefer to test new product/application ideas based on small scale investments, which are typically possible for short-term, low-risk approaches. Once the products show some level of market success, further steps towards long-term, high-risk ideas are possible.

Also, it is important to consider how the suggested use cases are related to current industrial trends; if a self-growing concept/solution is fully in-line with such industrial trends, the industrial exploitation may be straightforward. In the case that such a concept/solution is unaligned with current trends and potentially even fully disruptive, the possible industrialization requires more thinking – traditional industries may be hard to convince, except if the perspective of massive revenue can be demonstrated; an alternative approach may consist in exploiting those approaches for the set-up of new businesses, eventually based on risk-capital.

In the sequel, some indications on the industrial relevance of the various use cases are given. Those will include indications on how the relevance of use cases can be potentially increased during the further processing steps.

4.3.1 *Use Case "Energy Optimisation in a moving vehicle with capacity and coverage limits" (see D1.1, section 4.1.1)*

The usage of cellular communication in a train leads to numerous challenges with respect to current industrial solutions for WiMAX, 3GPP, etc. related system implementations. For example, the next generation WiMAX (IEEE 802.16m) based standard, deals with mobility up to 500 km/h at the most (as stated in [14] "Vehicular speeds in excess of 350 km/h and up to 500 km/h may be considered depending on frequency band and deployment"; furthermore it is stated: "High Speed Vehicular 120 - 350 km/h System should be able to maintain connection"). In practice, it must be expected that the communication will be extremely unreliable for high-speed trains if no additional mobility means are implemented into specialized products. It is thus proposed to consider this use case under the condition that common-off-the-shelf (COTS) equipment may be unsuitable, in particular for the communication between the Femto BS on top of the train and the WiMAX BTSs.

As a further item, it should be noted that in-train communication is nowadays handled by a specialized cellular system building on the GSM-R standard, taking train communication specific constraints into account. However, the GSM-R system is not intended to be opened to the broad public; it is rather limited for internal usage by railroad companies [20]. It is thus potentially possible to consider the proposed Relaying/WiMAX based approach as a potential alternative to the GSM-R system. This may open a new industrial aspect to the proposed solution.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	The level of industrial relevance is expected to depend on the possibility to use (to a certain extend) common-off-the-shelf (COTS) equipment. If COTS equipment can be used, the scenario is definitely of relevance to the large manufacturers. In case that complex modifications are required (e.g. for dealing with ultra-high mobility), the use case is rather relevant for smaller industries addressing niche markets.
Specific relevance for component manufacturers	In terms of Radio Front-End design, the use case is not expected to cause major problems. The most relevant factor may be high Doppler shifts, but COTS filter design is expected to deal with this. Concerning the base-band processing, it is expected that specialized high-mobility algorithms need to be implemented on top of COTS implementations – at least for the extremely high levels of mobility that can be achieved by high speed trains.

Item	Comment
Specific relevance for infrastructure manufacturers	The relevance lies in manufacturing equipment being able to cope with the rapidly changing radio environment. The research focus should be on methods which can fit into existing standards.
Specific relevance for mobile device manufacturers:	Mobile Device Manufacturers need to decide whether new device classes are introduced for train/ultra-high-speed scenarios. Also, the interoperability of devices for the various classes needs to be considered.
Specific relevance for Cellular Operators	Operator's main aspect is concentrated on transmission, routing, deployment and configuration issues and of course market share and revenues. Concern is mostly on being able to provide appropriate coverage and satisfying QoS to passengers.
Time line for Industrial Relevance	The application in trains is of immediate relevance with the market being present already today.

Table 4-17: Industrial analysis – UC-01/OTE.

The relevance of the use case to industrial usage can be further increased by considering how COTS equipment can be applied in order to serve the proposed purpose. Also, it is recommended to further position the proposed approaches with respect to GSM-R technology.

4.3.2 *Use Case "Energy Optimisation in an Office environment under coverage constraints" (see D1.1, section 4.1.2)*

This home/office use case represents a large market for both communication devices and sensor networks. Also, it is expected that COTS equipment is applied in such a framework and no specific niche-market adaptations or similar are required. It is thus of high interest to industries such as short range AP/device manufacturers (for home/office deployment of short range communication systems), cellular infrastructure/mobile device manufacturers and operators (for cellular backbone connections, etc.) as well as home entertainment industry (e.g., for wireless video distribution in the home, etc.), sensor network manufacturers and, possibly, others.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	The broad market potential of home/office deployment and the inherent sensor-network based optimization of the operational parameters is appealing to a vast number of industries, including short range AP/device manufacturers (for home/office deployment of short range communication systems), cellular infrastructure/mobile device manufacturers and operators (for cellular backbone connections, etc.) as well as home entertainment industry (e.g., for wireless video distribution in the home, etc.), sensor network manufacturers, etc.
Specific relevance for component manufacturers:	In terms of components, typically two types are expected to be distinguished: i) Ultra-Low-Cost components with specialized, but very limited functionalities for the sensor nodes and ii) components for infrastructure and user equipment providing advanced features and a high level of flexibility. Both markets are appealing due to the large size of the expected market.
Specific relevance for infrastructure	The business lies in upgrading WiMAX and 3GPP BSs by software capable to perform remote fast switch-on/switch-off. Both WiMAX and 3GPP

Item	Comment
manufacturers:	standards are affected when switch-on/switch-off is performed remotely.
Specific relevance for mobile device manufacturers:	The proposed use case is also of high relevance to mobile device manufacturers (including manufacturers of home entertainment devices building on wireless communication) due to the expected large market volumes and the broad applicability of a standard (COTS) product type.
Specific relevance for Cellular Operators	Operators' goal is to offer seamless connectivity to both large enterprises and small medium business at the minimum cost. This use case is of high importance for service providers due to the revenues and market share increase that can be accomplished while providing new competitive positioning. This can be achieved if being able to provide high speeds while avoiding wide deployment of wired infrastructure.
Time line for Industrial Relevance	The need for the proposed use case is of immediate relevance, but the availability of suitable sensor devices is expected to take some time. A mass market deployment is expected within a few years.

Table 4-18: Industrial analysis – UC-02/NKUA.

The relevance of the use case to industrial usage can be further increased by considering the functionalities of the sensor network in further detail. In particular:

- Is the sensor network RAT- specific?
- Is frequency band specific sensing applied?
- Do the sensor nodes need to support a broad level of functionalities?

From the industrial perspective it is preferable to deliver a large number of quasi-identical sensor devices.

4.3.3 *Use Case "Energy Optimisation for Self-Growing Office environment under coverage and capacity constraints" (see D1.1, section 4.1.3)*

This home/office use case is closely related to the one presented in Section 4.3.2. The main difference consists in integrating various WSNs. From the industrial perspective, there is an even broader application of sensor networks and thus the main relevance is related to corresponding components and devices.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	See Section 4.3.2. Additional relevance lies in the broader deployment of WSNs.
Specific relevance for component manufacturers:	See Section 4.3.2.
Specific relevance for infrastructure manufacturers:	See Section 4.3.2.
Specific relevance for mobile device manufacturers:	See Section 4.3.2.
Specific relevance	See Section 4.3.2.

Item	Comment
for Cellular Operators	
Time line for Industrial Relevance	Similar to the use case of 4.3.2, the need for the proposed The Use case is of immediate relevance, but the availability of suitable sensor devices is expected to take some time. Since the addressed WSN functionalities are expected to be more complex compared to those in section 4.3.2, further delays are expected until a broad industry support is available. A mass market deployment is expected within a few years.

Table 4-19: Industrial analysis – UC-03/NKUA.

The relevance of the use case to industrial usage can be further increased by considering the functionalities of additional sensor nodes: Are these nodes of quasi-identical characteristic positioned at another location or are additional sensor node features required? From the industrial perspective it is preferable to deliver a large number of quasi-identical sensor devices.

4.3.4 *Use Case "Network reconfiguration following the introduction of new nodes" (see D1.1, section 4.1.4)*

This home/office use case is an extension to the ones presented in Section 4.3.2 and 4.3.3. In particular, it is assumed that part of the nodes is not accessible for reconfiguration (e.g., they are owned by a neighbour, etc.). Also, it is proposed that the sensing tasks are performed by standard communication devices and not by specialized (low-cost) sensor nodes. This introduces uncertainty of the geo-location of the measurement device, but avoids the deployment of specific sensor nodes and is thus eventually more straightforward accepted by the mass market.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	In contrast to sections 4.3.2 and 4.3.3, the industrial relevance is concentrated on the deployment of COTS equipment, (partially) enriched by self-management features for re-parameterization of network nodes.
Specific relevance for component manufacturers:	The aspects for component manufacturers lie in the mass-production of feature-rich device components and infrastructure components. It is preferable that COTS components are applied with additional features being added for example by software updates.
Specific relevance for infrastructure manufacturers:	The business lies in upgrading WiMAX and 3GPP BSs and Femto stations with software capable of performing SON function such as Self-awareness and Self-configuration and performing remote switch-on/switch-off. WiMAX, 3GPP and OMA standards are affected when SON functions are performed. Both WiMAX and 3GPP standards are affected when switch-on/switch-off is performed remotely.
Specific relevance for mobile device manufacturers:	The aspects for mobile device manufacturers lie in the mass-production of feature-rich devices.
Specific relevance for Cellular Operators	Operator's main aspect is concentrated on the deployment of the node in terms of time, cost, service provisioning etc. and its interaction with the rest of the network.
Time line for Industrial Relevance	Similar to the use cases of sections 4.3.2 and 4.3.3, the proposed use case is of immediate relevance, but the availability of broadly reconfigurable devices is expected to take some time, i.e., further delays are expected

Item	Comment
	until a broad industry support is available. A mass market deployment is expected within a few years.

Table 4-20: Industrial analysis – UC-04/IFX.

The relevance of the use case to industrial usage can be further increased by outlining how the re-parameterization and self-management features, which are expected to be software solutions, are added to COTS equipment. In case that specialized solutions are required, it is of industrial interest to know whether this concerns all or only some network nodes and whether all components (i.e. RF front-end, base-band, etc.) or only some selected components are concerned.

4.3.5 *Use Case "Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks" (see D1.1, section 4.1.5)*

Similar to the use cases that are presented in sections 4.3.2, 4.3.3, and 4.3.4, the home/office use case is of great industrial interest due to the expected huge mass market. Due to the simplistic reconfiguration choices (switch on/off), the time-line for mass-market deployment relevance is expected to be far more immediate compared to the aforementioned solutions.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	The industrial relevance is concentrated on the deployment of COTS equipment, (partially) enriched by (self-) management features for re-parameterization of network nodes – with re-parameterization being limited to switch-on, switch-off commands.
Specific relevance for component manufacturers:	The aspects for component manufacturers lie in the mass-production of feature-rich device components and infrastructure components. It is preferable that COTS components are applied with additionally features being added for example by software updates. It is expected that switch-on/switch-off features can be straightforwardly included into COTS equipment.
Specific relevance for infrastructure manufacturers:	The relevance lies in that lower interference levels are possible through switch-on, switch-off of individual cells. The RNC (eNB) software must be upgraded to incorporate the functions needed to negotiate power settings. 3GPP standards affected when BSs need to negotiate on their power settings.
Specific relevance for mobile device manufacturers:	The aspects for mobile device manufacturers lie in the mass-production of feature-rich devices.
Specific relevance for Cellular Operators	Operator's main aspect is concentrated mainly on fast responsiveness of the respective node and the adaptability of network especially concerning service provisioning.
Time line for Industrial Relevance	The time line for mass market relevance is at the very short term, since available COTS components are expected to be straightforwardly adapted to serve the purpose for providing switch-on / switch-off features.

Table 4-21: Industrial analysis – UC-05/HWSE.

The relevance of the use case to industrial usage can be further increased by outlining how the overall decision making process is implemented and who takes control of it. In particular, who decides when a device is switched on/off?

4.3.6 *Use Case "Cooperative DAS (Distributed Antenna System) nodes configuration" (see D1.1, section 4.1.6)*

This use case addresses an antenna deployment approach that is used on top of the infrastructure deployment. The additional antennas are fed by the corresponding BSs/APs and are configured (on/off, etc.) so that high overall resource (energy, spectrum resources, etc.) usage efficiency is reached. In particular, in a home/office environment such an approach is clearly disruptive from an industrial perspective; the question is open whether this can be accepted by the broad public and thus whether the approach is viable for a mass-market deployment. If it turns out to be accepted by the mass market, the approach can create a new market segment, e.g. for independent antenna nodes, etc. In case that it remains a niche market, the approach is likely to be interesting to smaller industries.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	From the industrial perspective, it needs to be seen whether the DAS approach is accepted by the mass market in the long run. If this is the case, the approach will create new segments for infrastructure manufacturers (distributed antenna nodes in the home/office environment, extended COTS equipment which is feeding those antenna stations and performing antenna usage optimizations, etc.) and component manufacturers (low cost components for distributed antenna stations, etc.).
Specific relevance for component manufacturers:	In case of a mass market acceptance, the prospect of a massive demand for distributed antenna components seems appealing and the most relevant element for the component manufacturers. From the component side, the infrastructure components are not expected to change substantially, except for more processing power being required for optimization purposes (which antennas are fed, which are switch-on/off, etc.).
Specific relevance for infrastructure manufacturers:	The challenge lies in the implementation of smart control algorithms leading to well-designed cooperation between the distributed antenna nodes. The central processor will probably consume more power but this has to be weighted with the gain achieved by using less transmission power.
Specific relevance for mobile device manufacturers:	The approach is expected to be transparent for mobile devices. The main difference may lie in the lower power consumption due to shorter communication paths and thus longer lifetime of mobile device batteries.
Specific relevance for Cellular Operators	This case is interesting in its operation since it provides increased reliability, due to better coverage and also offers the chance for reduced operational costs, mostly energy consumption. A significant factor however, is the cost of deployment.
Time line for Industrial Relevance	The time line for mass market relevance is at the rather long term, since the approach is rather disruptive and market acceptance first needs to be tested and finally extended.

Table 4-22: Industrial analysis – UC-06/HWSE.

The relevance of the use case to industrial usage can be further increased by outlining in follow-up studies the functionalities inherent to distributed antenna stations, the "technical competence" required by users in order to do a suitable home/office deployment, identifying the required cable installations / wireless links between distributed antenna stations and the serving stations, etc.

4.3.7 *Use Case "Cooperative relay for energy efficiency" (see D1.1, section 4.1.7)*

Similar to the use case 4.3.6, a disruptive approach is suggested by introducing interactions between relay nodes in order to achieve a high level of overall (energy, resource usage, etc.) efficiency. The industrial relevance of the approach needs to be further monitored with respect to its market acceptance in the future. In particular, it remains open whether users would actually acquire a large number of Femto BS to be installed in a home/office context, or that the operators would have to deploy such fixed relay stations, etc.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	From the industrial perspective, it needs to be seen whether the cooperative relay approach is accepted by the mass market in the long run. If it is the case, the approach will create new segments for infrastructure manufacturers (distributed relay nodes in the home/office and outdoor environment, etc.) and component manufacturers (low cost components for distributed relay nodes, etc.).
Specific relevance for component manufacturers:	The aspects for component manufacturers lie in the mass-production of low-cost relay node components. In case of a broad market acceptance of the proposed approach, a huge potential for large telecommunication industries is expected here.
Specific relevance for infrastructure manufacturers:	The relevance lies in system throughput improvement and energy efficiency through cooperative relay. The WiMAX and 3GPP BSs and relay nodes software must be upgraded to support the cooperation functionality. WiMAX and 3GPP standards are affected when BSs and relay nodes need to cooperate with each other.
Specific relevance for mobile device manufacturers:	The aspects for mobile device manufacturers lie in the mass-production of feature-rich devices.
Specific relevance for Cellular Operators	Although this case is required in certain cases, its feasibility relies on its cost of deployment.
Time line for Industrial Relevance	The time line for mass-market relevance is expected to be mid- to long term, since the approach is rather disruptive and market acceptance first needs to be tested and finally extended.

Table 4-23: Industrial analysis – UC-07/HWSE.

4.3.8 *Use Case "Energy Aware end-to-end delay optimisation" (see D1.1, section 4.1.8)*

This use case considers a deployment of sensor nodes in a given environment partially covered by a second type of network, e.g. IEEE 802.11 WLAN. During the lifetime of the sensor network, a change in its purpose occurs: in addition to existing functionality, nodes have to report on delay sensitive data to a data sink. For such, the sensor network has to be reconfigured: the routing of messages through the sensor node (multi-hop communication) and the sleep cycle of the sensor nodes has to be adjusted to meet the delay constraints. A cognitive decision entity uses this information to evaluate if a potential synergy of the partially deployed WLAN network with the sensor network can enable the new purpose at better energy cost. Integrating both networks enables additional routes from the sensor to the data sink.

This use case addresses the integration of low-cost M2M (Machine-to-Machine) communication based sensor nodes with traditional short-range networks.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	From an industrial perspective, a huge market potential is seen in the deployment of low-cost M2M devices, such as sensor nodes. M2M device standards are currently in elaboration and a massive introduction of such devices to the market is considered to be imminent. This use case addresses an application that is beyond such an initial introduction of sensor nodes: A combination of those nodes with existing short range networks is considered. This approach is expected to be definitely viable from an industrial and market perspective, but the corresponding standardization and market introduction steps are considered to be some years in the future.
Specific relevance for component manufacturers:	The use case is of extremely high relevance for component manufacturers, since the deployment of M2M device sensor nodes is expected to lead to a multi-million or even multi-billion devices market in the future
Specific relevance for infrastructure manufacturers:	The relevance lies in adaptation of the sensor and WLAN nodes to inform a cognitive decision entity about relevant parameters in order for it to perform decisions giving the lowest possible delay and best possible usage of the networks in terms of energy-efficiency.
Specific relevance for mobile device manufacturers:	The relevance for classical mobile device manufacturers (like mobile phone manufacturers) is currently unclear, since the role of mobile devices in the M2M context needs to be defined in further detail. It is possible, for example, that M2M based sensor nodes are introduced to the market without any correlation to the business of classical mobile device manufacturers. Another possibility is that mobile devices are integrated in such a sensor node context, which would make handset manufacturers a major player in this field.
Specific relevance for Cellular Operators	The relevance in this case lies on the dependence of the additional deployment of nodes able to support a sudden increase of required capacity and the acceptance of such cost by interested parties.
Time line for Industrial Relevance	While the market introduction of M2M sensor nodes is expected to be imminent, this use case addresses a corresponding future evolution (integrating M2M sensor nodes into a short-range communication infrastructure, etc.). Therefore, this use case is expected to play a rather disruptive role with a time-line of 3-5 years or longer.

Table 4-24: Industrial analysis – UC-08/Fraunhofer.

4.3.9 *Use Case "Purpose-driven network configuration during an emergency situation" (see D1.1, section 4.1.9)*

In this use case Sensor nodes are considered, forming an ad-hoc network. The network nodes are deployed in a given environment partially covered by a second type of network providing centralized, single-hop backbone access, e.g. IEEE 802.11 WLAN. Both networks had gone through the self-growing phase having resulted in an integrated, symbiotic network under the control of cognitive decision entities. An incident situation occurs (e.g. a fire in parts of a building). As a result, parts of the existing sensor node infrastructure are destroyed. Also, as a result of the incident situation, the metric driving the network configuration changes and the network has to fulfil a new purpose: an extremely long lifetime of the network is less important but sensing information has to be delivered in a timely manner. Besides, the sensor nodes have to additionally detect persons in the building or even track the movement of emergency responders. For such, coverage in specific areas has to be ensured. Cognitive decision engines detect this situation and decide on a network reconfiguration, possibly including the symbiotic effects of the integrated WLAN network to cope with the incident situation and its associated change in purpose.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in general	This use case is related to currently on-going M2M sensor node related standardization and product development efforts. It addresses features that are beyond the current state-of-the-art by introducing self-adaptation features, as they are required in the specific case of a disaster situation. It is therefore considered to be ahead of the current industrial efforts, but the relevance is expected to occur in a mid-term time-frame.
Specific relevance for component manufacturers:	See Section 4.3.2, **Error! Reference source not found.**.
Specific relevance for infrastructure manufacturers:	In addition to what is mentioned for use case in 4.3.8 the relevance lies in adaptation of the WLAN nodes to change their configuration to fulfil a new purpose.
Specific relevance for mobile device manufacturers:	This use case is expected to address mainly low-cost M2M sensor nodes. The only expected relation to handset devices (such as mobile phones) is expected to lie in a potential communication link between M2M and handset devices. It is thus considered to be of minor relevance to mobile device manufacturers.
Specific relevance for Cellular Operators	This case demands to be technically broadly pre-specified as a procedure but is marketable relevant on a per case basis.
Time line for Industrial Relevance	Since this use case represents a straightforward extension of the current M2M sensor node features, it is expected to have a mid-term time-frame for industrial relevance.

Table 4-25: Industrial analysis – UC-09/Fraunhofer.

4.3.10 *Use Case "Cognitive Coexistence and self-growing for white space operation" (see D1.1, section 4.1.10)*

This use case focuses on a locally deployed access point operating in white spaces in order to form a WLAN providing access to a small (company) network. During its lifetime, the capabilities of the device dynamically grow from an operation without coexistence to a fully coexisting operation mode with other white space devices deployed in the surrounding. In a second phase, the self-growing of the network, the purpose of the deployed network elements grows from only supporting nomadic mobility to additionally supporting seamless mobility for mobile users. These features are ensured, for example, by a cognitive decision engine that achieves separation in (used) spectrum by intelligently assigning valid spectrum portfolios to devices.

Items related to the possible industrialization of the proposed use case are given below:

Item	Comment
Industrial Relevance in	The general framework of opportunistic spectrum access, in particular related to opportunistic TV white space access, is expected to be of huge

general	industrial potential. The regulators (FCC in the US, CEPT (group SE43) in Europe) are currently preparing the framework for enabling the usage of such frequency bands and standardization efforts are already well advanced (e.g., IEEE 802.11af, ETSI, IEEE SCC41 ….). The introduction is thus expected to be imminent. The context addressed in this use case, in particular related to self-growing mechanisms, is expected to lie some years ahead, since clearly advanced novel features are required that are currently not considered in standardization and industrial product development efforts.
Specific relevance for component manufacturers:	White space devices are clearly of huge potential for component manufacturers, since a completely new class of devices is expected to enter the market. The integration of such devices into a self-growing framework is introducing new constraints that are currently rather novel for development teams and thus it is expected that some R&D efforts need to be invested before the actual product development can start.
Specific relevance for infrastructure manufacturers:	The business lies in upgrading WLAN nodes with the functionalities to report on the context (e.g. coverage or other interfering nodes) required by the cognitive engine, on the strategy for achieving a given purpose, on the capability to report spectrum efficiency usage per node or the capability to report node location.
Specific relevance for mobile device manufacturers:	White space features are likely to be considered as a novel add-on like any other short range communication standard. Furthermore, in recent standardization efforts (ETSI, etc.) White space based communication is currently under consideration for peer-to-peer communication and the set-up of ad-hoc networks. This framework is expected to be of high relevance to device manufacturers. The specific self-growing context is expected to represent a second step which is not considered closely for the immediate future. In a mid- to long-term perspective, however, it is considered to be of high relevance.
Specific relevance for Cellular Operators	Depends on the cost of the spectrum usage, existing network planning and local usage needs.
Time line for Industrial Relevance	The considered approach (i.e., building on self-growing paradigms) is considered to be beyond the time-line of current state-of-the-art opportunistic spectrum access / white space communication studies. It is expected to be of relevance in a mid- to long-term perspective.

Table 4-26: Industrial analysis – UC-10/Fraunhofer.

4.3.11 *Use Case "Energy optimisation of co-located wireless networks in a home/office environment" (see D1.1, section 4.1.11)*

This use case addresses a future framework of a high number of networks that are active in and around home/office environments. Hence, the number of mobile and wireless devices and networks is increasing, inevitably leading to an increase in the density of co-located wireless devices. Today the capacity of wireless networks is generally increased by adding wireless infrastructure (more access points, more sensor networks...). More important is the coordination and cooperation between co-located wireless networks & devices, in order to avoid undesired interference. Today, this leads to unnecessary energy wastage and further involves a lot of human interventions and manual calibrations/configurations, resulting in high commissioning and maintenance costs. Through advanced inter-network cooperation (involving negotiations and joint decisions for minimizing interference and energy consumption), this use case aims to offer autonomous solutions for coordinating or even merging (independent) co-located wireless networks, enabling more efficient service delivery and an extended reach of service usage.

Items related to the possible industrialization of the proposed use case are given below:

Item	***Comment***
Industrial Relevance in general	With the number of distinct wireless systems steadily rising (e.g., various cellular systems, various WiFi flavours (based on IEEE 802.11a/b/g/n/ac/ad/af), mobile WiMAX flavours (based on IEEE 802.16e/m), etc.), this use case is of continued interest for the industry – starting from now but also going well into the future, since it can be currently foreseen that the number of available wireless standards will considerably rise over the next few years.
Specific relevance for component manufacturers:	For a component manufacturer, an efficient energy management mechanism is a key sales argument and thus it is of utmost importance. The interactions between distinct standards is, however, a new paradigm that still needs to be better understood by R&D teams and thus corresponding exploratory work is required before it can be integrated into products.
Specific relevance for infrastructure manufacturers:	The business lies in upgrading the network elements with software capable of cooperatively performing remote and fast switch-on/switch-off. Depending on the used radio network technologies, relevant standards are affected. See also sections 4.3.2 and 4.3.3.
Specific relevance for mobile device manufacturers:	For mobile device manufactures, the efficient exploitation of the ever growing heterogeneous wireless framework is a key challenge. It is known that mobile device manufacturers are very active in virtually all standardization efforts in this field – which illustrates the importance. In the future, this aspect is expected to play an even more important role.
Specific relevance for Cellular Operators	See sections 4.3.2,4.3.3.
Time line for Industrial Relevance	The problem of efficiently exploiting the heterogeneous wireless framework needs to be addressed immediately. Even today, it is known that the available deployed systems are poorly exploited, taking into account the potential for efficiency improvement if systems would be efficiently selected based on user and application needs. For the introduction of inter-system coordination, however, some basic work is still required, since these are new challenges to industrial R&D teams. It is thus expected to be of relevance in a short- to mid-term perspective and it will play a key role for a long time ahead in the future.

Table 4-27: Industrial analysis – UC-11/IBBT.

4.3.12 *Use Case "Self-adaptation of a reconfigurable wireless terminal" (see D1.1, section 4.1.12)*

This use case addresses a home/office context, where a reconfigurable network element adapts its configuration to the network conditions in order to save energy. Traditionally, wireless systems are designed for the worst case, assuming the highest throughput has to be delivered even under the worst channel conditions. To meet the link budget constraints under these challenging conditions, systems need to be configured with the worst case configuration in each part of the system. Some well-known examples are: i) maximum output power for the PA, ii) highest modulation and code rate for the physical layer, iii) always on at the MAC layer, etc. Next to those considered parameters, reconfigurable network elements typically provide a broad range of low-level tuning knobs to adapt the operation of the system. Configuring those parameters at runtime, taking into account instantaneous operating conditions, can result in significant energy savings.

The self-adapting network element collects information about its application requirements, channel conditions, and learns about the collocated network in order to adapt its operating parameters to save energy. Depending on a predefined policy, the optimization objective of the self-adaptation is the local energy only or a global energy cost of the network or group of collocated networks.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	Self-adaptation based on available context information is already deployed in available products in some limited level of features. Typically, the available level of context information is low and consequently, the impact of the parameter optimization is limited. However, there is clearly a huge industrial potential for investigating more advanced possibilities in this direction. The market potential is huge, since this may apply to virtually all wireless devices and may represent a clear competitive advantage for the various manufacturers and vendors.
Specific relevance for component manufacturers:	Optimized parameterization of a wireless device is of vital interest to component manufacturers, since this is one of the key sales arguments.
Specific relevance for infrastructure manufacturers:	The business lies in upgrading the network elements with software capable to cooperatively adjusting and optimising its radio parameters. Depending on the used radio network technologies, relevant standards are affected. See also sec. 4.3.2 and 4.3.3.
Specific relevance for mobile device manufacturers:	It is considered to be important for mobile device manufacturers in the sense that they will select the components for their products which have the most advanced and optimized self-adaptation features. It is unlikely, however, that mobile device manufacturers would try to optimize those parameters themselves.
Specific relevance for Cellular Operators	The relevance of this case applies on the reduction of operational costs (energy savings).
Time line for Industrial Relevance	It is of immediate relevance in the currently limited framework of available context information and possibilities for system parameterization. It is expected that the degrees of freedom in system parameterization will rise in the future (including also the selection of other standards in a heterogeneous environment, the simultaneous operation of some standards, etc.). This topic is thus of short-, mid- and long-term relevance.

Table 4-28: Industrial analysis – UC-12/IMEC.

4.3.13 *Use Case "Home Monitoring Energy Optimization" (see D1.1, section 4.1.13)*

A smart home environment has a number of sensor and actuator nodes, with a wide variety of functions and capabilities. A gateway central node controls the collection and reporting of the data. The system grows with more devices added and more existing devices are placed under control of the energy management system. For efficiency and energy consumption reasons the system moves from a centralised polled system into a more decentralised one where collected data is summarised at intermediate points, and control is delegated to selected devices. The system needs to make the transition gradually to permit centralised and decentralised systems to cooperate.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	The deployment of sensors and actuators in a home/office environment is definitely of relevance, in particular in the framework of M2M devices. However, it is currently unclear how pure monitoring devices for a home/office environment would be accepted by the market. Would a user deploy small boxes in a home/office? Would it be better to integrate those in other products, like for example WiFi APs, TV sets, etc.? Would a user pay in the first place for energy monitoring? Before industrial development effort will start, an answer to those questions, among others, may be required. Consequently, the industrial relevance is not clear for the time being.
Specific relevance for component manufacturers:	In case that the questions related to market acceptance and introduction are resolved, this domain is definitely of high relevance for component manufacturers. In particular, a huge market for M2M sensor nodes is expected to occur in the future.
Specific relevance for infrastructure manufacturers:	The business lies in upgrading sensors (such as WLAN or ZigBee, etc) with software capable to perform sensor device reconfiguration. There is no impact on WiMAX and 3GPP standards.
Specific relevance for mobile device manufacturers:	The energy efficient configuration of communication links is key issue for handset manufacturers. It is unlikely that mobile device manufacturers will invest into the deployment of such sensor nodes themselves, but their products (i.e., mobile devices) will definitely exploit the provided information in order to ensure a more energy efficient communication.
Specific relevance for Cellular Operators	This case has no relevance to a cellular operator.
Time line for Industrial Relevance	Since some time is expected to be required for the clarification of market acceptance/introduction related issues, this use case is expected to be of mid- to long-term relevance.

Table 4-29: Industrial analysis – UC-13/TREL.

4.3.14 *Use Case "Cooperation Enablers in Home Gateway Environments" (see D1.1, section 4.1.14)*

In the home network scenario, the situation of multiple devices trying to access the same frequency resources is extremely common due to the explosion of networked devices within the home. In femtocells, even though communication is through licensed bands, due to the proximity of femtocells in dense areas, interference is still a very real problem, which may in particular affect subscribers of macro cells being close to femtocell-dense areas. Energy efficiency is also crucial to many mobile devices as it improves the battery life of the devices. In home networks, where mesh network is the common network topology, techniques such as physical layer network coding can be further applied to improve energy efficiency. Network coding may also be beneficial to relaying systems. The home gateway is also equipped with multiple access technologies such as mobile radio network, wireless LAN, home automation (mesh) network, and so on. Including this heterogeneous set-up in our considerations will enable further cooperation, relaying and environmental-awareness capabilities.

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	See Section 4.3.13: The same argumentation applies, in this use case with a focus on spectrum usage coordination between network nodes.
Specific relevance for component manufacturers:	See Section4.3.13: The same argumentation applies, in this use case with a focus on spectrum usage coordination between network nodes.
Specific relevance for infrastructure manufacturers:	Cooperative transmission by using network coding will require that new technologies are developed for the physical layer. If the results are promising from this research it can open up a big market for both mobile and infra-structure manufacturers.
Specific relevance for mobile device manufacturers:	See Section 4.3.13: The same argumentation applies, in this use case with a focus on spectrum usage coordination between network nodes.
Specific relevance for Cellular Operators	This case has no relevance to a cellular operator.
Time line for Industrial Relevance	See Section 4.3.13: The same argumentation applies, in this use case with a focus on spectrum usage coordination between network nodes.

Table 4-30: Industrial analysis – UC-14/TREL.

4.3.15 *Use Case "Dynamic Meeting Setup in Flexible Office/Building Environments" (see D1.1, section 4.1.15)*

In this use case, a company is considered which has reserved a public meeting room to hold a meeting with a few project partners. Some partners are from a branch office, some are from an external company, and some from a public authority. Thus, the various people in the meeting have different roles and different rights for using surrounding communication technologies or accessing resources of the other stakeholders (e.g. internal project files, public documents, source code etc.). Furthermore, an initial network access is provided by the owner of the public meeting room, but is temporary owned by the meeting organization company. The result is a quite complex and dynamically changing networking setup with several roles, rights, restrictions, and policies (e.g. some people use Wi-Fi, some LTE/femto, and some can communicate directly over Bluetooth).

Items related to the possible industrialization of the proposed use case are given below:

Item	*Comment*
Industrial Relevance in general	The use case of a dynamic meeting set-up is of key product relevance already today. Advanced features such as efficient exploitation of the heterogeneous wireless framework, advanced security features, etc. are expected to provide some further potential for R&D and product design.
Specific relevance for component manufacturers:	Component manufacturers are not expected to provide solutions that are specifically tailored to the dynamic meeting setup use case; rather, this is expected to be one important application for a wireless/wireline communication platform optimized to operate in a heterogeneous wireless

	environment and addressing advanced security issues.
Specific relevance for infrastructure manufacturers:	See sections 4.3.2 and 4.3.3.
Specific relevance for mobile device manufacturers:	The use case of a dynamic meeting set-up is expected to be of interest to mobile device manufacturers. It is expected to be one application among others to be provided by the mobile devices.
Specific relevance for Cellular Operators	See section 4.3.2, 4.3.3.
Time line for Industrial Relevance	Since this application is already deployed (while a future evolution is definitely envisaged building on advanced wireless/security features), the use case is considered to be of short- to mid-term relevance.

Table 4-31: Industrial analysis – UC-15/Fraunhofer.

4.3.16 *Use Case "Collaboration of Different Technologies" (see D1.1, section 4.1.16)*

In this use case, a printing and advertising company is considered that has expanded and requires three additional offices and a new printing room for high end printing devices. Thanks to the flexible building design it is more or less simple to move some walls and change the furniture. The building owner that leases the rooms uses a powerline based metering system (e.g. digitalSTROM or others) to logically separate the power grid used by a company for calculating the energy costs separately. Moreover, the printing company uses additional own wireless metering systems (e.g. ZigBee) for the printing devices to exactly calculate the energy costs for each printout. This scenario is an example for the interconnection of different types of communication technologies (powerline, wireless sensors, IP based backbone etc.) to build a virtual, self-growing network that allows to collectively achieving a goal.

Items related to the possible industrialization of the proposed use case are given below:

Item	***Comment***
Industrial Relevance in general	The use case combines various types of communication technologies (such as powerline, wireless sensors, IP-based backbone) and is thus closely related to the current large-scale activities in the framework of "power grids". It is currently unclear, though, how specific products will look like in the future. Further basic research and industrial R&D activities are required, before corresponding products can be developed.
Specific relevance for component manufacturers:	While the type of related products is quite unclear for the time being, it seems inevitable that corresponding components integrating various types of communication technologies (such as powerline, wireless sensors, and IP-based backbone) will be developed by component manufacturers. Still, considerable research and development effort is expected to be required before products may enter the market.
Specific relevance for infrastructure manufacturers:	The relevance lies in the adaptation of the infrastructure nodes to integrate their operation with all types of communication technologies (such as powerline, wireless sensors, IP-based backbone). This integration is a rather long-term product development.
Specific relevance for mobile device manufacturers:	Mobile Devices are expected to exploit such a framework integrating various types of communication technologies, but currently no specific mobile device related industrial R&D efforts are identified or planned due to the unclear situation of which future products will enter the market.

Specific relevance for Cellular Operators	This case has no relevance to a cellular operator.
Time line for Industrial Relevance	Due to the unclear situation with respect to future products, this activity is considered to be rather long-term from an industrial perspective.

Table 4-32: Industrial analysis – UC-16/Fraunhofer.

4.4 Use Cases: A summary

This section provides a summary of the evaluation of use cases which has been presented in the previous sections. Specifically, this summary captures:

- The relevance to the Self-Growing aspect. For each use case an initial "feeling" is expressed reflecting the level of relevance to the Self-Growing. At this initial stage each use case is characterised as either "Key" or "Contributing" to the Self-Growing,
- The level of interest of partners, as reflected by partners profile, regarding the aspects that are incorporated in each use case,
- The corresponding timeline,
- The potential relevance and impact on standardisation activities.

Use Case	Self- growing relevance	Industrial Interest	Timeline	Impact on standardisation
Energy Optimisation in a moving vehicle with capacity and coverage limits	Contributing	Depends on the usage of COTS equipment	Immediate relevance with today market	Solutions need to fit into existing standards.
Energy Optimisation in an Office environment under coverage constraints	Contributing	High interest, broad market potential.	Immediate relevance depends on the availability of suitable sensors.	WiMAX and 3GPP standards affected.
Energy Optimisation for Self-Growing Office environment under coverage and capacity constraints	Key	High interest, broad market potential.	Additional relevance lies in the broader deployment of WSNs.	No activities currently.
Network reconfiguration following the introduction of new nodes	Contributing	Industrial relevance is concentrated on the deployment of COTS equipment.	Availability of broadly reconfigurable devices is expected to take some time.	WiMAX, 3GPP and OMA standards are affected.
Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks	Contributing	Deployment of COTS equipment, enriched by (self-) management features.	Very short term.	3GPP standards are affected.

Cooperative DAS nodes configuration	Contributing	Open question whether the approach is viable for a mass market deployment.	Rather long term.	No activities currently.
Cooperative relay for Energy Efficiency	Contributing	Needs to be further monitored with respect to its market acceptance in the future.	Mid- to long term.	WiMAX and 3GPP standards are affected.
Energy-aware end-to-end delay optimization	Key	This approach is expected to be definitely viable from an industrial and market perspective.	Expected to play a disruptive role with a time-line of 3-5 years or longer.	Standardization introduction steps are considered to be some years in the future.
Purpose-driven network configuration during an emergency situation	Key	Ahead of the current industrial efforts	Mid-term time-frame	No activities currently.
Cognitive Coexistence and self-growing for white space operation	Key	Expected to be of huge industrial potential.	Mid- to long-term perspective	Well- advanced standardization efforts.
Energy optimisation of co-located wireless networks in a home/office environment	Key	Continued interest for the industry.	Short- to mid-term perspective.	Depending on the used radio network technologies, relevant standards are affected
Self-adaptation of a reconfigurable wireless terminal	Enabling	Huge market potential.	Short-, mid- and long-term relevance.	Depending on the used radio network technologies, relevant standards are affected
Home Monitoring Energy Optimization	Contributing	The industrial relevance is not clear for the time being.	Mid- to long-term relevance.	No impact on WiMAX and 3GPP standards.
Cooperation Enablers in Home Gateway Environments	Enabling	The industrial relevance is not clear for the time being.	Mid- to long-term relevance.	No impact on WiMAX and 3GPP standards.
Dynamic Meeting Setup in Flexible Office/Building	Key	Advanced features are expected to provide some further	Short- to mid-term relevance.	No activities currently.

Environments		potential for R&D and product design.		
Collaboration of Different Technologies	Key	Further basic research and industrial R&D activities are required, before corresponding products can be developed.	Rather long-term.	No activities currently.

Table 4-33: Summarisation of use cases.

4.5 Identification of Self-growing types

Self-growing as a key benefit for a novel type of network is determined mainly by a set of enabling attributes as detailed in the scope of D1.1 and further elaborated by section 3. As stated there, the relevance of certain enabling attributes accredited to a scenario or use case further determines the specific characteristic of a self-growing network.

For example, the main aspect "change of functionality" (see section 3.1) indicates high relevance of enabling parameters related to reconfigurability and cooperation in general, and on situation awareness, energy awareness, coexistence and spectral efficiency in detail – depending on the specific use case, operational environment and evolutional history of the network.

A type classification based on a (potentially implicit) weighting of the contribution from certain enabling parameters to the key benefit, allows identifying types of self-growing that are important regarding business perspectives (e.g., by considering market relevance of certain attributes), technological impact (e.g., by looking on a predicted implementation time line of enabling attributes) or socioeconomic impact (e.g., considering potential energy conservation achieved through some attributes). It should be mentioned that the exact classification is not performed by D4.1 but is part of subsequent work in WP4. Nevertheless, the methodology is available and the following explanations are valid since they do not depend on an exact specification of types.

The identification of self-growing types assumes an extensive analysis of business models and implementation aspects. Such a classification will also be used as a basis to determine which types of self-growing networks can be demonstrated and/or deployed.

At this stage and from an industrial perspective, an initial set of complementary aspects to be taken into account for the classification of the Self-growing types/approaches are

- The time line for industrial relevance
  - In particular, it is important to outline the intermediate steps which are required for ensuring a broad market acceptance. Those intermediate steps may also be taken into account for the classification of Self-growing types.
- The required pre-development steps
  - In particular, required actions in standardization bodies need to be identified before the actual product development (and even potentially the market assessment) can be started. Also, it needs to be identified whether a modification of existing standards is sufficient or whether an entire new class of self-growing technology related standards need to be created – at least for some of the use cases.
- The level of disruptiveness / migration

  - It is essential to classify the various Self-growing types by identifying changes in the required behaviour of customers (i.e., do customers need to deploy additional nodes such as distributed antennas, relays, etc. which they are not used to today?); also, required changes and inherent risks with respect to COTS equipment needs to be taken into account,
  - Following the level of disruptiveness, a self-growing type can be attributed to classical industries if mass market acceptance is likely; in case of high-risk in terms of broad market acceptance, smaller industries may be the preferred target, e.g. with niche market products, etc.
- The most impacted product types by a given self-growing type
  - Is the component manufacturing industry required to profoundly change component design?
  - Is the network infrastructure industry required to profoundly change the type of nodes to be deployed? Which back-bone computation and node interconnection requirements are coming up?
  - Is the handset manufacturing industry required to change the way the mobile devices are interacting with the (new) infrastructure? E.g., do we need to maintain multiple links simultaneously; is the continuous and dynamic reconfiguration of supported RATs required, etc.?
  - Is the network operator industry required to change the business model? Are new types of services provided that may open new markets?
- Are new markets / new market players expected for a given self-growing type?
  - New distributed antenna systems may create a new market of distributed antenna nodes,
  - For example, the deployment of relay nodes may lead to a new branch of relay node operators that work independently of existing industries and they may offer relaying services to existing industries,
- Deployment approach for a given self-growing type
  - Is a wide-area deployment (e.g. across a city, etc.) or a deployment within a small area targeted (e.g. within a home/office environment)?
- Type of gain for a given self-growing type
  - User related benefit,
  - Is the benefit related to a more homogeneous availability of Quality of Service (e.g. no sudden drop of network throughput, shadowing, etc.)?
  - Is the benefit related to an increase of Quality of Service to all users, a selected group of users (closed subscriber group, etc.), etc.?
- Operator related gain
  - Is the Quality of Service to users ensured by a lower deployment cost?
  - Are energy efficiency benefits achieved, e.g. the OPEX decreases?
  - Is the required level of maintenance decreased?

The next steps will include the application of the extended methodology to refined use cases and requirements towards the framework definition.

5. CONSERN Self-growing Framework

5.1 Framework Outline

As defined in [17], [18] a Framework is "a real or conceptual structure intended to serve as a support or guide for the building of something that expands the structure (i.e., architecture) into something useful". In many cases a framework encompasses a set of assumptions, concepts, processes, and practices; moreover a framework may summarize a set of functions and/or components within a system including the interrelations between the mentioned concepts. A framework is generally more prescriptive than architecture.

In the CONSERN context, the Self-Growing Framework should at least comprise:

- The use cases and scenarios: initially, all scenarios and use cases (as in CONSERN Deliverable D1.1 [12]). Based on the further elaboration on use cases analysis and selections, the use cases will be part of the framework in different degrees, according to the value they provide in terms of required functionality and benefits,
- The identified and used attributes and parameters: they reflect different aspects and details of the self-growing concepts, and their involvement in the framework will be refined based on the analyses that will be performed to identify and highlight the correlation between the different types of attributes which have been defined in [12], namely, key benefits, enabling attributes, and efficiency attributes,
- The reference architecture based on the requirements and the functionality which is identified in previous sections. The application of the architecture will be modelled by the use cases and scenarios. The grade of generality is rather changing between scenarios and use cases. A scenario can be seen as an application of one or more use cases, and the set of all use cases exceeds the sum of all scenarios,
- The tools, methods and algorithms used to evaluate the benefit as well as the environment needed to provide the testing/operating context (either real or simulated) as initiated in section 5.4,

The Framework will be refined as needed in order to integrate additional contributions for achieving a clear definition of the architecture and how it is applied, realized and verified.

The Framework outline is depicted in Figure 5-1.

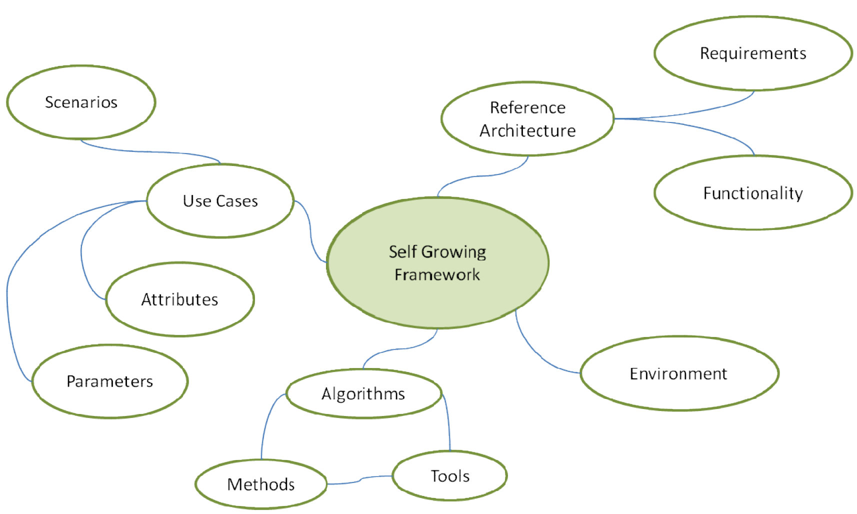


Figure 5-1: Outline of the Self-Growing Framework.

5.2 Transition from System to Functional Requirements

D1.1 section 5 elaborated on generic system requirements, that is, on functional and non-functional requirements from an overall system perspective. Following the methodology outlined in section 3, system requirements here are derived from the list of parameters associated with the key benefit and its enabling attributes.

Resulting from this approach, this section will focus on an initial specification of functional requirements that can be derived from analysing parameters based on their relevance for realizing the key benefit. We hereby assume that parameters can be mapped to functions either controlling or monitoring this parameter, and that the resulting set of functions can be mapped to architectural components such as network nodes, services, or software modules. In a subsequent step functional requirements will be utilized to define framework components.

For example, assuming that a set of rules implements the network behaviour realizing the purposes, the parameter "Change in set of purposes a network supports" is related to changes in the rule base and depends on decision making capacities. Table 5-1elaborates further on this example.

Parameter		***Change in set of purposes a network supports***
Related to		Change in rule base
	Depends on	Decision making
		Existing rule base
		Methods to modify a rule (learning, imitating, management)
		Methods to modify a rule base.
Related to		Change in topology
	Depends on	Change in connectivity between network nodes
		Change in node population
		Change in node configuration
Related to		Change in functionality
	Depends on	Integrating functions
		Removing functions
		Suspending functions
Functional Requirements		The system shall change its rule base, topology or functionality to satisfy an external request to change its purposes.
		The system shall decide and modify its rule base or distinct rules from this rule base if this is required to enable a change of purposes.
		The system shall adopt, suspend or remove functions if this is required to enable a change of purposes.
		The system shall change topology, connectivity or node population if this is required to enable adoption, suspending or removal of functions.

Table 5-1: Sample analysis of a parameter to derive functional requirements related to self-growing.

The specification of non-functional requirements in terms of system constraints and quality of service is left to subsequent documents.

5.3 Self-Growing Functionality Identification

In this section the methodology is extended to derive the functionality based on the system requirements as defined in D1.1 by means of use case evaluations. For the identification of functions the following steps have been performed:

- Identify the self-growing use cases i.e., the ones who have "Self-Growing" as its highlighted attribute in D1.1 and/or has at least one self-growing parameter in its list of parameters.
- Analyse the technical requirements and the action entries of the description and derive relevant functions,
- For each function look into the list of parameters to identify relevant parameters required for this function,
- Classify the function according to following dimensions:
    - A function of the network vs. a function of a node,
    - Centralised (requires one specific node) vs. distributed,
    - Monitoring vs. information processing/distribution vs. control.
- Name the function and give a short description,
- Find and list all functions this function interacts with,
- Identify the authorised actor from the list of actors who may be the owners of this function.

Based on this approach a list of functions has been derived. Each function is presented by one tabular entry which includes the following information:

- Name: a unique name for the function,
- Description: a short description,
- Use case: list of associated use case(s),
- Scope: indicating whether this is a function of the network or a function of individual nodes,
- Distribution: indicates whether the function is performed centralised, hierarchically or decentralised/distributed,
- Type: indicating the type of function. Primarily the following types of functions are foreseen
    - Monitoring/sensing,
    - Configuration/control, and,
    - Information distribution/exchange.

  Others types of functions are also possible and should be added in due course,
- Parameters: list of associated parameters,
- Function relations: interactions with other functions,
- Actor relations: possible authorised actors.

The following list of functions has been identified:

Name	Sensor Coordinator
Description	A functional entity responsible to collect information from a set of sensors and make it available to other functions.

Use case(s)	*UC-02/NKUA:* Energy Optimisation in an Office environment under coverage constraints. *UC-03/NKUA*: Energy Optimisation in an Office environment under capacity and coverage constraints. *UC-04/IFX*: Network reconfiguration following the introduction of new nodes. *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimization.
Parameters	Data collected from sensors
Scope	One coordinating entity
Control	Centralised collection of sensor data
Type	Information processing and distribution
Related functions	Network Configuration
Actors	Sensor Coordinator, CONSERN module

Name	**Network Configuration**
Description	A function responsible for the configuration and operation of network elements
Use case(s)	*UC-02/NKUA*: Energy Optimisation in an Office environment under coverage constraints *UC-03/NKUA*: Energy Optimisation in an Office environment under capacity and coverage constraints. *UC-04/IFX*: Network reconfiguration following the introduction of new nodes. *UC-05/HWSE*: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks. *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimization. *UC-09/Fraunhofer*: Purpose-driven network configuration during an emergency situation. *UC-10/Fraunhofer*: Cognitive Coexistence and self-growing for white space operation. *UC-13/TREL*: Home Monitoring Energy Optimization
Parameters	Energy required for transmission and during idle mode, number of active/inactive nodes,
Scope	Network
Control	Distributed (decision making) between network nodes
Type	Configuration control
Related functions	Sensor coordinator (to receive sensor information input)
Actors	Network operator, CONSERN module

Name	Information exchange
Description	A function responsible for information exchange between the network components, such as Sensors and/or a Sensor Coordinator, relay nodes
Use case(s)	*UC-04/IFX*: Network reconfiguration following the introduction of new nodes *UC-05/HWSE*: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks. *UC-07/HWSE*: Cooperative relay for Energy Efficiency *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimization. *UC-09/Fraunhofer*: Purpose-driven network configuration during an emergency situation. *UC-10/Fraunhofer*: Cognitive Coexistence and self-growing for white space operation. *UC-13/TREL*: Home Monitoring Energy Optimization *UC-14/TREL*: Cooperation Enablers in Home Gateway Environments
Parameters	Data collected from network components such as sensors, relay nodes, etc.
Scope	Individual network components
Control	Distributed (Information exchange) between network elements
Type	Information distribution/exchange
Related functions	Sensor Coordinator, CONSERN module, Network Configuration
Actors	Network components, Sensors and /or a Sensor Coordinator, CONSERN module, relay nodes, Home Gateway

Name	Knowledge sharing
Description	Decision and operating command distribution among network elements on balancing autonomic capabilities, cooperative operation, etc.
Use case(s)	*UC-04/IFX*: Network reconfiguration following the introduction of new nodes *UC-05/HWSE*: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks. *UC-07/HWSE*: Cooperative relay for Energy Efficiency *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimization. *UC-09/Fraunhofer*: Purpose-driven network configuration during an emergency situation. *UC-10/Fraunhofer*: Cognitive Coexistence and self-growing for white space operation. *UC-13/TREL*: Home Monitoring Energy Optimization *UC-14/TREL*: Cooperation Enablers in Home Gateway Environments
Parameters	Preferable operation, parameters to be adjusted

Scope	Individual network nodes
Control	Distributed (Information exchange) between network nodes or distributed by central control entities
Type	Information distribution/exchange
Related functions	Network Configuration
Actors	Network nodes such as sensors and /or a Sensor Coordinator, relay nodes, Home Gateway

Name	**Information awareness/learning**
Description	Collecting and learning the communication environment information such as network topology, channel information, traffic load, neighbour nodes statistics and etc.
Use case(s)	*UC-05/HWSE*: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks. *UC-07/HWSE*: Cooperative relay for Energy Efficiency. *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimisation. *UC-09/Fraunhofer*: Purpose-driven network configuration during an emergency situation. *UC-10/Fraunhofer*: Cognitive Coexistence and self-growing for white space operation. *UC-14/TREL*: Cooperation Enablers in Home Gateway Environments
Parameters	CQI, traffic load, neighbour nodes statistics, etc.
Scope	Individual network nodes
Control	Distributed (information learning) between network nodes
Type	Monitoring/sensing
Related functions	Decision making, information exchange
Actors	Relay nodes, Home Gateway

Name	**Decision Making**
Description	Distributed operation decision (cooperative decision) making based on learned information
Use case(s)	*UC-05/HWSE*: Switch on-off of nodes for Energy Efficiency in Heterogeneous Networks. *UC-07/HWSE*: Cooperative relay for Energy Efficiency. *UC-08/Fraunhofer*: Energy Aware end-to-end delay optimisation. *UC-09/Fraunhofer*: Purpose-driven network configuration during an emergency

	situation. *UC-10/Fraunhofer*: Cognitive Coexistence and self-growing for white space operation. *UC-14/TREL*: Cooperation Enablers in Home Gateway Environments.
Parameters	Related operation parameters, such as energy required for cooperative transmitting, cooperative partners, cooperation algorithm and related parameters, network coding support policy
Scope	Individual network nodes or network control point
Control	Distributed control between network nodes or controlled by central nodes
Type	Configuration/control
Related functions	Information exchange, Knowledge sharing
Actors	Relay nodes, Home Gateway

Name	Central Gateway Device
Description	A gateway central node controls the collection and reports the data
Use case(s)	*UC-13/TREL*: Home Monitoring Energy Optimization
Parameters	Data to be reported, data collected from sensors
Scope	One coordinating entity
Control	Centralised collection and report of sensor data
Type	Information processing and distribution
Related functions	Network Configuration
Actors	Network Configuration, CONSERN device

5.4 Requirements to the External Environment

Previous sections elaborated on the functional decomposition of use cases and discussed further steps needed to develop a functional architecture from these. In addition to this system architecture, the framework also has to consider the environment enveloping the self-growing network for development, testing, operational and management purposes.

For **development** of decision making engines (i.e., the rule base) a well-known operating environment is needed that allows generating dedicated external events (i.e., stimuli) to a self-growing network. Functions (i.e., software modules) that interface to the operating environment must be replaced by simulated and/or pre-recorded environment aspects to control the stochastic behaviour of a cognitive network due to its operational history. These functions must be designed as plug-in replacements, such that the system developed must not be aware of the simulated or partially simulated environment. This aims to provide a stable (i.e., reproducible) training environment for optimizing the cognitive functions of a self-growing network.

For **testing** during development as well as during a subsequent operational phase, functions that interface to the operating environment are replaced by partially simulated/stored environment aspects on-demand. This is especially of interest if functions that are usually only utilized under special or exceptional operational conditions must be tested. Putting dedicated stimuli to the network (e.g., forcing partial reconfigurations) and observing the network's reaction can be utilized both for offline testing as well as for the verification of preparedness to respond with a foreseen reaction to a certain external condition.

During **network** operations it must be possible to supervise the self-learning process of a self-growing network if necessary to ensure proper responses to external conditions, which requires capturing internal states of the network in a suitable way enabling the network state to be transferred into a simulations environment for evaluation. For example, after some time of operation the rule base of a self-growing network may have been evolved making it difficult to predict the behaviour of the network when responding to an external condition. An off-line evaluation based on a snapshot of the current operational context in conjunction with the current rule base allows verifying basic correctness of the network's behaviour. For a detailed analysis dedicated stimuli may be applied using the testing functions described above. Changes in the network configuration and/or in the rule base may be observed as a result of these stimuli. Clearly, the latter must be applied carefully to not disrupt regular operations of the network.

Aside conventional network management, **management** of a self-growing network includes all the aspects of development, testing and operational functionality as discussed above. Further, upload of network operational context parameters, rule base and state of decision making engines as well as download and modification of rules and functions must be enabled by integrated management functions. Since it cannot be assumed that a deployed network is able to respond to any thinkable external condition in a correct way, management functions of the network must be able to detect situations where decision-making may fail (e.g., due to a lack of appropriate rules) to request human operators to jump in for failsafe operation.

Functions for testing and management as described above are assumed of some complexity due to the interaction of the various parameters monitored by the cognitive functions of a self-growing network. It thus is a reasonable assumption that these functions are cooperative and cognitive by themselves.

6. Summary

This very first deliverable of CONSERN WP4 establishes the basic reference for the Self-growing concepts. The Self-growing definition together with a set of key definitions provides a coherent description of the novel paradigm of the Self-growing attribute of a network which has been introduced by CONSERN. Such concepts include the lifecycle of the self-growing network, the progression points as associated to a set of attributes, the network purposes and the benefit of a transition between purposes. The network lifecycle and transitions are to be governed by a (extensible/adaptable) set of rules. With this description the self-growing is also clearly differentiated from other SOTA approaches on network management and evolution, such as for example the Self-Organising networks.

Elaborating on this the Self-growing is interrelated to self-x capabilities and the cooperation/collaboration paradigms. Prior to this, the mentioned paradigms are briefly described in order to set the reference context in which self-growing is introduced. Such interrelation is further modelled to reflect two different perspectives, namely, on different level.

D4.1 defines also an extended methodology for elaborating on Self-growing concept and functions. This extended methodology elaborates on the methodology defined in the context of WP1 and described by CONSERN deliverable D1.1 [12], and describes the approach for further analysis of CONSERN use cases, attributes and parameters with respect to the Self-growing key benefit.

Moreover, a number of self-growing types were elaborated in order to drive the initial use case analysis. Specifically, scalability (the ability of a system to accommodate changes in transaction volume without major changes to the system and to continue to function well when it is changed in size or volume) and evolvability (the ability of a system to evolve its structure, scope, size or any other characteristic in order to meet the users' needs in an autonomic way) are considered key enabling technologies for self-growing.

Based on these considerations the whole portfolio of use cases has been analysed in terms of:

- Relevance to self-growing attribute, classes and parameters,
- Identification of key beneficiaries,
- Relevance and interest to current industry activities (including manufacturers and operators),
- Respective timeline for industrial adoption per use case, and,
- Potential impact on existing standards and standardisation activities.

In consequence an initial set of complementary aspects to be taken into account for the classification of the Self-growing types/approaches from an industrial perspective were identified; next steps will include the application of the extended methodology to the refined use cases and requirements towards a completion of the framework definition.

D4.1 concluds with the self-growing framework specified so far in terms of:

- The framework components definition,
- The transition from system requirements to functional requirements within the scope of WP4, building on the parameters that detail self-growing as an attribute,
- Identification of the Self-growing functionality as a set of functions and functional blocks, which are defined to take care of the tasks related to self-growing, and,

- The requirements to the external environment, thus considering the environment enveloping the self-growing network for development, testing, operational and management purposes.

D4.1 provides a coherent basis for the different working items within WP4. This will lead to the next step of the work, including (in the short term):

- Elaboration on self-growing types,
- Selection of Use Cases that best capture the Self-growing aspects, based on the technical and business/technological analysis of this deliverable,
- Specification of the self-growing architecture, based on the requirements and functionality definition, and,
- Refinement of the Self-Growing Framework, based on the above-mentioned steps.

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