PROJECT PERIODIC REPORT

Grant Agreement number: 248993

Project acronym: LOLA

Project title: Achieving Low-Latency in Wireless Communications

Funding Scheme: STREP ICT-2009-1.1

Date of latest version of Annex I against which the assessment will be made:

Periodic report: **1st ☐ 2nd 3rd ☐ X 4th ☐**

Period covered: **from 1st of January 2012 to 1st of April 2013**

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[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Declaration by the scientific representative of the project coordinator1

I, as scientific representative of the coordinator[1] of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):
  - X has fully achieved its objectives and technical goals for the period;
  - ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations[3];
  - ☐ has failed to achieve critical objectives and/or is not at all on schedule[4].
- The public website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator[1]: ...Knopp, Raymond.....

Date: ....14../ 06...../ 2013.....

Signature of scientific representative of the Coordinator[1]: .....

[3] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

[4] If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

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1 Publishable summary

1.1 Project Concept and Objectives

The purpose of LOLA is to provide significant technological advances in terms of minimizing end-to-end latency in wireless systems for low-latency application scenarios found in machine-to-machine (M2M) communications and highly-interactive services such as gaming. As shown in figure below, the target network topologies and application areas are twofold:

1. Topology A: Highly-interactive IP-based two-way services on LTE/LTE-A networks
2. Topology B: Low and high-rate data communications for short-to-medium range rapidly-deployable wireless mesh networks

Topology A considers high-performance gaming applications, two-way realtime machine-to-machine (M2M) applications; while topology B applies mainly to application scenarios found in civil protection networks or industrial automation networks.

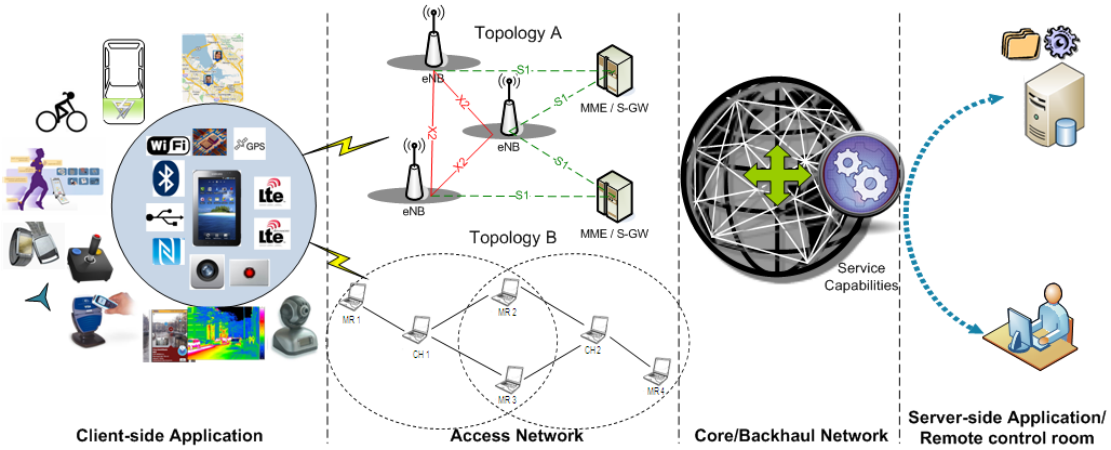

Figure 1 Application space and Access Topology applied to LOLA

In LOLA we analyze and model M2M and online gaming traffic characteristics through measurements for a subset of scenarios, and study the impact of such traffic on transmission latency in order to design and prototype low-latency transmission techniques in the access network. In addition to fundamental aspects of low-latency transmission, two real-time validation platforms and one field trial are considered for a subset of the considered application scenarios.

Based on this traffic analysis study, LOLA project proposes a new approach and innovative techniques to support low-latency robust and spectrally-efficient transmission in set of real-time application scenarios. When dealing with machine-type application combined with the standard application like VoIP and multimedia communication, the issue of resource management in presence of a high density of users (humans and, now, machines) in high loaded condition becomes a key factor. Moreover, the sparcity of some realtime M2M applications set new challenges to AMC design and scheduling, and in particular in the presence of relay or multiple hops among devices. Through low latency transmission, LOLA also addresses reduction in energy consumption for M2M devices. To this end, Lola project targets three major objectives:

1. **Fundamental:** innovations with respect to extremely low latency application
   - Definition of scenarios and use-cases
   - Characterization and modeling of traffic
   - PHY/MAC design : procedures, algorithms, and scheduling
2. **Experimental:** Rapid prototyping based on existing open-source technology
   - Testbed 1 : Large-scale system emulator and traffic measurement testbench (PHY/MAC/L3)
   - Testbed 2 : Real-time Link validation platform (PHY)
   - Testbed 3 : rapidly-deployable mesh, full-system demonstrator with mini field-trial
3. **Standardization:** Inputs to 3GPP and M2M Working Groups

1.2 Work Performed and Main Results Achieved

1.2.1 WP2 – Scenarios and Target System Architectures

This WP was completed during the first 6 months of the project, as expected. The work of WP2 consisted in defining the application scenarios to be targeted in the LOLA project. The scenarios have been briefly evaluated, key requirements/issues (latency target, latency bottlenecks) identified and highlighted and mapped to the topologies (Topology A is the cellular deployment as in LTE/LTE-A, Tolopogy B is the rapidly deployable mesh network) and the testbeds targeted in LOLA. Another task of WP2 was to provide an initial framework for the architecture elements studied and specified in detail in the other WPs. In particular, notions of latency, the target network topologies and the sources of latency in current systems have been described. Initial guidelines for the traffic measurement and modelling methodologies in the LTE-A cellular topology have been provided. In addition, the scene for the latency-reducing MAC/PHY adaptations to both LTE/LTE-A and rapidly-deployable mesh network topologies for the considered applications has been set. Two deliverables were produced: D2.1: Target Application Scenarios and D2.2: Target System Architectures.

1.2.2 WP3 – Traffic measurements and Modelling

In the third year of the project the focus was threefold. First we tuned the exiting solutions obtained in year two, e.g., traffic models and verified measurement results from previous campaigns with new extended runs. Second we worked on the basic parameters to obtain performance values as a benchmark for the upcoming finishing of WP5 and finally third we focused on publications of the results from the previous years. In the context of the first topic we conducted several new measurements in Vienna with TUV, Ericsson and MTS, resulting in a better understanding of the impact, the M2M traffic has on existing infrastructures. This also lead to a better understanding in the direction KPI could be useful for WP5, e.g., number of active users per cell, which was the second main topic of this period. In this topic we studied extensively the question how to compare different networks with one measurement performance. A new methodology was presented to evaluate delay in networks and resulting a new way of assessment for network delay was constructed. These results together with the measurements and the work done in the year before lead to the submission of two journal publications, one book chapter, and several high class papers, which was the third focus point for the last period, namely dissemination activities.

1.2.3 WP4 – PHY/MAC Algorithms

Activities carried out in WP4 during year 3 were oriented to the analysis of a final set of adaptations at PHY and MAC layers on Topology A and B architectures in order to lower latency. The adaptations fall in the areas of Adaptive Modulation and Coding (AMC), Hybrid Automatic Repeat reQuest (HARQ) and traffic scheduling, especially related to Rel-10 and Rel-11 3GPP new features like Carrier Aggregation (CA) and Coordinated Multi-Point transmission and reception (CoMP). Efforts were put on the enhancement of the simulation environments to enable the study of the different adaptations in topology A. As far as Topology B is concerned the focus was on deriving the final results of an innovative cooperative broadcasting technique based on automatic, retransmissions and Decode and Forward strategy. These results were compared with the ones of the baseline broadcasting strategy obtained during year 2. Another important activity of the period was the specification of a HARQ strategy combined with MAC forwarding and distributed Alamouti for inter-cluster communications. Finally, the LOLA solution package for Topology B was presented. Three deliverables were produced: D4.3 Adaptive Modulation and Coding Scheme and Hybrid ARQ Mechanism v3.0, D4.4 Adaptive Modulation and Coding Scheme for Hybrid Analog/Digital Transmission v3.0 and D4.5 Scheduling Policies for M2M and Gaming Traffic v3.0. These are the final versions of these three deliverables are expected by M39.

1.2.4 WP5 – Integration and Validation

In the third year, the project focused on the development and the integration of WP3 traffic models and WP4 adaptation in the tesbed 1 and 2, and the development of the mesh relay and a collaborative logical link in the tesbed 3. For each testbed, the hardware and software platform integration and detailed validation scenarios are defined.

As for the testbed1, we redesigned the platform to run on a multicore computing node architecture allowing repeatable and realistic emulation in controlled environment for large-scale LTE/LTE-A system emulation using. Such emulation platform allows preparing and validating the WP4 adaptation before the real experimentation by providing the baselines for protocol validation and integration, performance evaluation and pre-deployment system and application testing. In addition, the platform is available remotely for online experimentation. The LTE access stratum protocol stack have been further developed and tested against LTE Rel 8.6 for compliance. Extensions for the FDD and TDD frame type have been developed. In testbed2, progress has been made to guarantee interoperability between the AT4LP eNB and OpenAirInterface UE as well as to integrate a number of WP4 adaptations for the analysis of the performance achieved in a more realistic and real-time environment. Several compliance tests have been performed between the two platforms. For the testbed 3, an emulation platform for a rapidly deployable mesh network based on LTE PHY/MAC has been built for integration and validation of the mesh relaying and collaborative logical link before the field trail. This implied a phase of software development at PHY, MAC, RRC level mainly, with iterations for specifications updates, as well as the hardware bring up for the MIMO express RF card and its integration with the software.

1.2.5 WP6 – Dissemination and Standardization Activities

The main part of dissemination during the third year of the project has been done through research papers published or submitted to international journals and conferences. In this period three special sessions devoted on topics considered in this project has been held and another one has been prepared. The developed software applications have been made publicly available through various channels. Another three contributions to the LTE RAN Enhancements for Diverse Data Applications Working Group has been accepted during the period. The project has also been presented on posters and by demonstrations on several meetings and summits during the year.

1.3 Expected Impact and Exploitation

Low-latency transmission is becoming a key factor to improve the efficacy and/or quality of experience of emerging real-time M2M and interactive multiplayer gaming applications. In one of the recent studies for LTE Release 11 related to radio access improvement for machine-type communications (MTC), overhead and latency reduction are identified as the first priority. It will represent a key technology advances on the way to future low latency wireless communications networks, and thus major impacts are expected. In order to make the concept of low latency transmission applicable, the results of LOLA are expected to provide inputs to standardization groups and regulation authorities such as 3GPP and ETSI. The project will thus contribute to the development of future networks.

An impact on the competitiveness of European telecommunications industry and academia is also expected. Indeed, the results of LOLA should help them to take a strong position in the development of key technologies for future wireless broadband services in emerging applications. Hence, LOLA will help reinforcing European industrial strengths in wireless networks and developing stronger synergies between the various actors of the sector. New services and business opportunities are also expected to emerge from the low latency concept. The scenarios considered in LOLA will help to identify new industrial opportunities in Europe in terms of services and architecture for the mobile Internet and applications. The outcome of LOLA will be also exploited by the consortium as described in the following subsections.

1.3.1 ERICSSON D.O.O. FOR TELECOMMUNICATIONS

EYU is using the participation in the project and the results of the projects both internally in the company and externally towards customers and general population.

Internally, the results of the project are exploited in several ways:

- For general advancement of knowledge of Ericsson employees.
- As an important input into the overall research activities in the company feeding both M2M research and LTE related research as well as LTE system development
- Outputs of LOLA the project were also distributed shared with to Ericsson standardization group and are used by them as an input into preparation of Ericsson standardization contributions.
- The work and the tools implemented in WP3 for evaluation of the traffic impact are being considered as a basis for a potential commercial service.

Externally, the project activities are exploited in the following manner:

- As an input into global marketing material, promoting Ericsson brand and connecting it with innovation and advance technology.
- For use in their activities. Further to the internal activities, the project results are also used for as the basis for presentations given to the customers, researchers and general population at scientific conferences, trade events and in media.
- In discussions with the current and potential customers in relation to the performance of the mobile networks in the presence of M2M traffic
- Fostering collaboration with in the region in addition to Telekom Serbia as one of the main customers.

Through the collaborative research with Telekom Serbia, was able to foster relationship and opening opportunities to work together with them on development of their network and services. In particular, the results of the impact of M2M traffic were used when such an incident was detected in a live network.

1.3.2 THALES COMMUNICATIONS and SECURITY

TCS recently announced the launch of its professional LTE solution, called NEXIUM Wireless, and of its ruggedized mission-critical smartphone TeSquad. This system is able to offer LTE connectivity (and also with other old standard) and to offer traditional PMR services at the same time. The NEXIUM system works actually on band 4, 14, 17, 20, i.e. bands which have been allocated to PMR services in North and South America. Currently, NEXIUM Wireless can be deployed in full network mode (with operated via a core network) or in isolated mode with one eNodeB without core network. Today NEXIUM Wireless does not support the wireless mesh network mode (many eNodeB connected in a wireless network without a cabled core network). The effort in LOLA is inscribed in the evolution of NEXIUM Wireless towards the support of a fully wireless mesh network mode, which is supposed to be achieved in the medium/long term. In this framework, there are still a number of technical issues that must be solved and TCS will use LOLA results for development of internal competences and engineering studies on the topic of static mesh networks based on 3GPP LTE for private mobile radio (PMR) communications. The knowledge acquired on the LTE and LTE-Advanced systems will also be valuable for issues related to the convergence of PRM networks and Beyond-3G cellular networks. . Studies and results in LOLA are also interesting for technologies linked to sensor networks, like surveillance camera networks. Finally, the most advances research topics dealt with by the project will feed internal discussions on future research projects and their corresponding proposals. Last but not least, LOLA participates to feed the internal roadmap on advanced studies of the team which was leading the LOLA studies (the Waveform Design team).

1.3.3 TELEKOM SERBIA

MTS (Telekom Serbia) is aware of a fact that capability of offering demanding M2M and Online gaming will make main differences among operators. The project will be used to increase knowledge, identify shortcomings of existing technologies faced with emerging new applications and better understand feasibility of services. Extensive testing performed in Telekom Srbija 3G/HSPA network within D3.5 and D5.3 has revealed serious shortcomings of existing HSPA network faced with M2M and Online Gaming traffic. Telekom Srbija was able to assess the levels of impact through several upgrades of the network. Even with no visible impact on main network KPIs that would alarm an operator in terms of degraded network performance, the quality of service for the end-user in terms of latency required further network upgrades. The knowledge obtained was twofold:

- Network performance: the testing revealed that even a small number of users with such persistent uplink-oriented traffic, relatively to the available resources, may lead to severe network performance degradation. The upgrades needed to improve network performance are more than those for the same number of traditional users (mostly downlink oriented traffic, bursty uplink traffic).
- Quality of service for M2M and Online Gaming users in terms of latency: Though many M2M applications are not latency-critical, the testing revealed that for those who are, the RAN network needs to be quite unloaded in terms of available resources in order to support the QoS, relatively to the number of M2M users. The secondary RAN network KPIs were identified that could serve for assessing the level of traffic load impact on latency. As well, concerning core network features, performance of different APNs was tested, and APNs that should not be used for conveying these types of data traffic are identified.

Meanwhile, a real large-scale M2M application was deployed, Telekom Srbija being just the connectivity provider, not the service provider, and not fully aware of the subject traffic patterns. The degradation of same KPIs as during testing was observed, jeopardizing the service for traditional users. This proved that these types of massive services require specific and careful approach. Through comparison of testing and real-world results the mechanism of impact on RAN network was identified, as well as methods for overcoming these effects – optimization, new network architecture and topology, aggregation of traffic.
Telekom Serbia currently offers M2M services on individual basis, providing connectivity only. A unique M2M core platform is planned to be deployed, that would enable Telekom to become an application provider offering E2E M2M solutions. Telekom Srbija intends to apply the obtained knowledge on shaping its further offers, as a network and service provider, planning network scenarios for these services, pre-assessment of necessary conditions and planning the RAN network.

1.3.4 AT4 WIRELESS

During the project inception and the first two years of LOLA, the AT4 wireless' exploitation plans were well defined and known. LOLA helped the AT4 wireless link-based simulation environment evolve by integrating a number of WP4 adaptations (described in D4.3 and D4.5). The simulation environment was therefore made more powerful and AT4 wireless exploited the improvements to cover a wider range of simulation scenarios. Those simulation results allowed taking a decision on what adaptations could best be integrated in the WP5 test bed 2. Concerning WP5 outcomes, the AT4LP had been improved to support basic TDD functionality to allow interconnection with the OpenAirInterface platform from EURE. Interoperability checks with other TDD UE implementations have also been performed. This opened a wider range of UEs that could potentially be connected to the AT4LP in the near future in any of the two duplex modes (FDD and TDD). Concerning WP3, AT4 wireless would exploit traffic traces and models developed to be included in the AT4LP. This would allow testing a wider range of traffic scenarios in test bed 2. AT4 wireless would continue using outcomes in the

different WPs to improve its visibility within 3GPP with the provision of pertinent contributions (as already done during Y2).

Agilent Technologies, Inc. acquired AT4 wireless' Test Systems Division in August 2012, including the LTE/LTE-A simulation environment and the AT4LP eNB emulator. This operation had a significant impact on the AT4 wireless exploitation plans for the LOLA results. AT4 wireless has made a tremendous effort to keep its commitment with the consortium and finalize all LOLA tasks, especially those that required the use of now Agilent's hardware and software IP.

As a direct consequence of the operation, AT4 wireless will not be able to exploit WP4 and WP5 outcomes the same way as intended during the project inception.

On one hand, thanks to a long-term relationship and fruitful cooperation between Agilent Technologies and AT4 wireless, LOLA WP4 and WP5 results can be now exploited by Agilent Technologies. This fact has a multiplier effect on the exploitation of LOLA results, because the Agilent's marketing and sales network can make LOLA outcomes reach a wider and larger dimension.

On the other hand, AT4 wireless is working hard to provision performance testing services for wireless and cellular network operators. AT4 wireless can therefore exploit WP3 traffic models to help network operators find how their networks perform for applications like those whose traffic has been modelled in WP3. In addition, AT4 wireless has recently acquired another LTE eNB emulator and test system from a different provider where LOLA WP3 traffic models and LOLA WP4 scheduling algorithms can be integrated for further exploitation.

1.3.5 TECHNISCHE UNIVERSITAET WIEN

The TuV will use the results of the LOLA project to improve the understanding of the interaction between the design processes of traffic models with the underlying transport network. Recently the knowledge about M2M traffic allowed the TuV to acquire first research projects with local funding in on the impact of M2M traffic onto life networks due to the high interest of industry partners on this topic.

The work on delay monitoring and reproducible measurements for mobile cellular networks lead to a better understanding, which itself will drive a new side-track of research and according publications. The close interworking with EURECOM lead to knowledge transfer in the OpenAir simulator, which the TuV plans to use in follow up projects for simulation purposes.

The academic impact for the TuV are two journal submissions, two book chapters and more than ten high level paper publications.

1.3.6 LINKOPINGS UNIVERSITET

During the third year of the project the LiU group has enhanced its hardware programming activities due to the involvement in the LOLA project. Apart from its strong position in the theoretic research field, practical hardware implementations and simulations has been made possible due to the people hired to work in the project. Some of the developed software is used in undergraduate courses and the acquired knowledge has been used for updating the course contents with the latest achievements in the field. The LiU group's involvement in LOLA has extended the team's contacts with industry partners in Sweden and abroad as well as other research groups in Europe.

1.3.7 EURECOM

Eurecom will use LOLA outcomes to promote the OpenAirInterface inlab system validation and RF platforms as a unique open-source implementation of LTE/LTE-A as well as mesh extension for LTE. The results of the project will also enrich the education offer with the novel concepts and system design principles that are identified and developed during the project. Some of the wireless communication topics and networking algorithm, protocols, and architecture tackled in the project will become part of master courses, as well as argument for master and PhD theses.

1.4 Project Information

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Project Website: http://www.ict-lola.eu/
Duration: Jan. 2010 – March 2013 (39 month)
Funding Scheme: STREP
Total Cost: 4.1 M€
EC Contribution: 2.6 M€
Contract Number: INFSO-ICT-248993

2 Project objectives for the period

2.1 Global Objectives in Year 3

The third period allowed to obtain new WP3 traffic models and their corresponding KPIs for emerging M2M and online gaming application and to specify MAC/PHY techniques in support of low-latency transmission in the access network defining. Significant progress has been made on the validation of the proposed WP4 protocol and algorithm through inlab system validation platform provided by the OpenAirInterface platforms. The selected outcomes of WP3 and WP4 have been integrated with the three testbeds.

- In WP2, we refined the application scenarios in which low-latency has a significant interest. These scenarios will be found in the area of, but not restricted to, Machine-to-Machine (M2M) and Online gaming. WP2 shall also provide basic system architectures and requirements especially to WP3 for traffic measurement and modelling studies and to WP4 related to PHY/MAC techniques design, for both topologies (LTE-advanced cellular topology and mesh topology) considered in the LOLA project.
- There were two main objectives in WP3. The first objective was the derivation of traffic models for the sources defined in D2.2 applicable to the WP5. This was done in a combined step for M2M, online gaming and background traffic in form of the deliverable D3.5. The second objective was the definition of a performance metric for the transport network improvements done in WP4. This was also completed.
- As for the WP4, the global objective was to finalize the study of PHY/MAC adaptations with the analysis of a new set of techniques falling in the areas of AMC and HARQ (D4.3), hybrid analog and digital transmission (D4.4) and scheduling (D4.5), both for topologies A and B. In addition, and according to recommendations from the EC reviewers, the consortium included the objective of coming up with a set of selected WP4 adaptations, referred to as LOLA Solution Package. Adaptations included in the LOLA Solution Package are intended to show a significant balance among latency reduction, complexity increase and energy efficiency.
- In WP5, the main focus of the third year was the implementations and integration of the selected WP3 models and KPIs and WP4 algorithms into the Testbeds. Validation results for testbed 1 and testbed 2 have been obtained, while for testbed 3 will be reported after the final demo.
- In WP6, the focus was on increasing the visibility of the project results for both the scientific communities and industries. Achieving higher impact on standardization has been another main objectives of WP6 during this period. Other objectives were to contribute the software/hardware blocks to the opensource community. .

2.2 Recommendations from Review Year 3

In addition to the initial objectives listed above, the consortium built an action plan to take into account the recommendations from the Period 1 review. This section reminds the actions and explains how they were taken into account.

- **Action 1:** revise the conditionally accepted deliverables, namely D3.5, D4.2, D4.3, D5.4, and D6.2
  Status: all the deliverables have been revised and send to the PO on 29/06/2012 and updated on the Lola website, private area.
- **Action 2 :** thorough check of the deliverable before the submission
  Status : The submitted deliverables were reviewed by the WP leader and the technical coordinator.
- **Action 3:** Improve the visibility of the new content in the deliverable
  Status: All the new contents are tagged with (new), the updated contents are tagged (updated).
- **Action 4:** Publication in the internationally recognized Journal and Magazine

Status : Three journal paper were published and four more have been submitted for journal publication during the period.

- **Action 5:** improve the presentation of exploitation plan
  Status : The section exploitation plan is restructured, a series of slides has been send to the PO on the plan of each partner.
- **Action 5:** KPIs for online gaming and M2M
  Status: we gathered a better understanding on main impacts for a mobile network considering M2M and online gaming traffic, and updated the KPI parameters accordingly. In addition we also created a methodology to compare the results between different network configurations.
- **Action 6:** provide a LOLA system solution
  Status: the LOLA system solution to reduce the latency in LTE/LTE-A as well as in mesh network is presented in the last section of deliverables D4.3 and D4.5. The recommended WP4 adaptations are classified based on the latency gain, complexity increase, and energy-efficiency.
- **Action 7:** Continuous update the website
  Status: The website now includes all the relevant information and materials about the project. Project summary, concept, and objectives as well as project structure have been improved.
- **Action 8:** 3-months project extension
  Status : Following the recommendation of the reviewers and the PO, we requested a cost-neutral 3-months extensions. This extension has been accepted.
- **Action 9:** involve the potential users and stakeholders outside of the consortium
  Status : Three main contacts have been made. First, we have organized a half-day workshop on 8th of November 2012 with the A1, telecom operator in Austria, where the results of the LOLA project has been presented and thoroughly discussed within the A1's M2M workgroup. The workshop did provide a valuable input to the A1 for their offer for the M2M service. We also presented the result of the LOLA project at ETSI M2M workshop to a large number of potential users. Second, Eurecom organized a half-day meeting with the Orange-labs Sophia Antipolis discussing about how LTE could be an interesting solution for the distribution of the electricity, for example Tele-protection in the Medium Voltage network, where latency is a key requirement. The LOLA testbed 1 with the integrated M2M traffic model proved to be interesting for Orange-lab to perform the measurement. Third, EURE also presented the results of the LOLA project to the www.com4innov.com/ platform, mainly, the latency model, traffic models, and WP4 adaptation. In particular, we provided them the TG-APP developed by Ericsson/MTS for the experimentation on the platform.

2.3 WP3 – Traffic measurements and Modelling

LEADER: TUV

Partners: EURE, TUV, EYU, MTS

Start month: M3 **End month**: M36

2.3.1 Progress

The activities of WP3 span over the whole duration of the project from M3 to M36. Within this working time the project is split into four Tasks. These tasks cover the steps from defining a measurement methodology, defining the measurement setup, executing the traffic measurements and finally modeling the traffic generated by the applications under test. Presented in brief detail these tasks are:

- Task 3.1 Measurement and Modeling Methodology for Targeted Architectures. Starting from the application scenarios and network architecture elements and defined in WP1, this task specifies the system requirements, parameters, performance requirements and any other aspects that would be a relevant input for the measurement and modeling activity carried out in WP3.

- Task 3.2 Configuration of the Measurement Scenarios on TUV/Mobilkom Test Cell. This task concerns the configuration of M2M and Gaming clients for traffic measurement. It depends on the scenario descriptions (T2.1) and basic system architectures (T2.2/T3.1)
- Task 3.3 Traffic Measurements. This tasks concerns measurements for applications defined in D2.2 mapped to applications available in nowadays technologies. It concerns measurements for online gaming, both for TCP and UDP based applications as well as video surveillance and M2M clients. The measurement outputs will be converted into traces for traffic generators used in WP5.
- Task 3.4 Traffic Modeling. This task provides models for M2M and Online Gaming traffic for mobile networks based on the measurement activity in T3.2. The models are implemented in traffic generators for the WP5 emulation system. Finally, QoS metrics for M2M and online gaming are determined and used as performance indicators to drive MAC scheduling algorithms. Based on WP5 emulator measurements the modeling activity will be reiterated in order to refine the models.

Progress of each Task in year three of the project :

- Task 3.1: This task was finished in year 1 of the project resulting in D3.1 defining the measurement scenarios of the project.
- Task 3.2: Task 3.2. was finished in year 1 of the project implementing the setup defined in D3.1 and reported in the deliverable D3.2
- Task 3.3: In the original plan this task also ended in year one of the project. However, we decided to continue refining the results from the first measurement runs with new extended results. The new information was put into the deliverables D5.3 and used in D3.6 as in updating D3.5. The task was finished at the end of the project.
- Task 3.4: This task was started in year 2 of the project at full rate. The results of this work haven been compiled into a single deliverable merging the traffic modeling methodology, the traffic models for M2M, online gaming and the background traffic into a complete set. In year three we updated these results and implanted the traffic models into a Linux environment for improved delay measurements. A new methodology derived in the project allowed us to compare different network setups. At the end of this task the traffic models were implemented into the LTE emulator of EURECOM for further use in WP4 and WP5. The task was finished at the end of the project.

2.3.2 Contribution

The partners have contributed according to the description below:

1. **TuV** was the lead contractor of WP3. The main activities done in the second year were:
   - Conduct measurements in HSPA network together with MTS and EYU
   - Finalizing D3.5 – editing, rework results based on new measurements
   - Finalizing D3.6 – editing, new measurement strategies
   - Development of a delay measurement methodology independent of the network in charge
   - Implement and conduct measurements with traffic generators developed in Year 2 of the project.
2. **Eurecom's** main contributions were:
   - Contributed to D3.5, and D3.6
   - Develop a simple M2M traffic model framework for the scenario described in D2.1

- Implement an M2M/online gaming traffic generator for testbed 1 based on the models developed in WP3
- Implement the KPIs in the D3.6 for the testbed 1, testbed2, and testbed 3

3. **EYU**: Ericsson's main contributions were
   - Development of a traffic generation mobile phone application for different scenarios used in traffic measurement test cases
   - Extensive measurements done on live Node Bs together with MTS, including upgrade of the base station with additional HSPA licenses provided by Ericsson.
   - Evaluation of the measurements and preparation of contributions to D3.5.
   - Preparation and presentation of several papers summarizing the results: WONS 2012: "Traffic generation application for simulating online games and M2M applications via wireless networks ", esIoT 2012 "Impact of Online Games and M2M Applications Traffic on the Performance of HSPA Radio Access Networks", 6th KuVS workshop "M2M traffic influence on WCDMA/HSPA Network Performance", Telfor 2012 "HSPA radio access performance evaluation for Online games and M2M applications traffic (TCP vs UDP)".
4. **MTS'** main contributions were:
   - Extensive measurements on live network together with EYU, involving upgrade of NodeB and modernization of the network
   - Comprehensive analysis of recorded traces – phone traffic traces and application reports, Gn interface traffic traces, firewall traces, cell statistics, making the Test Case reports included into the D3.5
   - Cross-checking of the Deliverable D3.5
   - Preparation and presentation of several papers resulting from D3.5 measurements: Traffic generation application for simulating online games and M2M applications via wireless networks (WONS 2012), Impact of Online Games and M2M Applications Traffic on the Performance of HSPA Radio Access Networks (esIoT 2012), M2M traffic influence on WCDMA/HSPA Network Performance (6th KuVS workshop), HSPA radio access performance evaluation for Online games and M2M applications traffic (TCP vs UDP) (Telfor).
   - Preparation a conference paper resulting from D3.5 - The impact of HSPA core network features on latency for M2M and OG-like traffic patterns
   - Invited presentation at Fraunhofer FOKUS FUSECO Forum (M2M simulations and real applications in HSPA network – impact on network performance and service) as a follow up to participation at KuVS workshop Berlin
   - Project presentation with main results from D3.5 emphasized at Telfor Belgrade

2.3.3 Significant Results

The significant results for year three were:

- Extensive traffic measurements done on the live Telekom Srbija mobile network for different traffic scenarios and different configurations of the network (access & core)
- Impacts of M2M and Online Gaming traffic on HSPA network observed through D3.5 testing confirmed through real massive M2M deployment
- Implementation of traffic models from D3.5 into an automatic measurement environment
- Conduct measurements with the newly implemented traffic system
- Derive a methodology to compare different cellular networks.
- Conclude compare-able KPI parameters

2.4 WP4 – PHY/MAC Algorithms

LEADER: AT4

Partners: EURE, TCS, LIU, AT4

Start month: M1 **End month**: M36

2.4.1 Progress

WP4 activities extend all along the whole duration of the project. WP4 work is organized into five tasks which are briefly presented below:

- Task 4.1 Specification of PHY/MAC Adaptations, where specifications of algorithmic and structural adaptations to network topologies considered in WP2 at the PHY/MAC layers with the aim of reducing latency are to be provided. This task extends from M1 to M10.
- Task 4.2 Framing and Low-Layer Signalling, where adaptations/enhancements to framing and low-layer signalling in both topologies A and B are to be proposed and studied to allow for low-latency transmission in the access stratum. This task extends from M4 to M18.
- Task 4.3 AMC and HARQ, where adaptations/enhancements to the existing AMC and HARQ mechanisms in topologies A and B are to be designed and studied. This task extends from M4 to M36.
- Task 4.4 AMC for hybrid analog/digital transmission, where the design of basic two-way coding and modulation for analog sources typical in remote sensing/actuation and hybrid digital-analog transmission strategies are to be developed. This task extends from M4 to M36.
- Task 4.5 Traffic Scheduling Policies, where the problem of MAC-layer scheduling for M2M traffic on top of the LTE and rapidly deployable mesh network air interfaces is tackled. Attention is also paid to co-existence between conventional consumer services and those dedicated to M2M. This task extends from M4 to M36.

The objectives for each of the WP4 tasks in Year 3 are summarized below:

- Task 4.1 Specification of PHY/MAC adaptations: This task finished in Year 1 having the specification of PHY/MAC adaptations for the Topologies A and B in the form of the deliverable D4.1 Specification of PHY/MAC Adaptations for the Target Architectures. No additional work is expected for this Task during Year 3.
- Task 4.2 Enhancements to Framing and Low-Layer Signalling: This task started in Year 1, in parallel to the period where the first adaptations were to be developed, and finished in Year 2. No additional work is expected for this Task during Year 3.
- Task 4.3 AMC and HARQ: This task starts in Year 1, period when the first batch of adaptations was released in the form of the deliverable D4.3 Adaptive Modulation and Coding Scheme and Hybrid ARQ Mechanism. The task continued in Year 2, where the second batch of adaptations was released. Task 4.3 objectives for Year 3 are twofold; on one hand, the last set of announced adaptations need to be carried out; on the other hand, the consortium has to elaborate a selection of the most convenient Task 4.3 adaptations to be part of the LOLA Solution Package.
- Task 4.4 AMC for hybrid analog/digital transmission: This task started in Year 1, and the first batch of adaptations was released in the form of the deliverable D4.4 Adaptive Modulation and Coding Scheme for Hybrid Analog/Digital Transmission. The task continued in Year 2, where the second batch of adaptations was released.
- Task 4.5 Traffic Scheduling Policies: This task starts in Year 1, period when the first batch of adaptations was released in the form of the deliverable D4.5 Scheduling Policies for M2M and Gaming Traffic. The task continued in Year 2, where the second batch of adaptations was released. Task 4.5 objectives for Year 3 are twofold; on one hand, the last set of announced

adaptations need to be carried out; on the other hand, the consortium has to elaborate a selection of the most convenient Task 4.5 adaptations to be part of the LOLA Solution Package.

Progress made in Year 3 within each of the WP4 tasks is detailed above:

- Task 4.1: Not applicable.
- Task 4.2: Not applicable.
- Task 4.3: Deliverable D4.3 Adaptive Modulation and Coding Scheme and Hybrid ARQ Mechanism v3.0 was generated during Year 3. As far as Topology B is concerned, the definition of a HARQ strategy for inter-cluster cooperative communications based over distributed Alamouti scheme plus Decode and Forward was presented. The performance of this proposal was evaluated by simulation. The LOLA solution package of this task for Topology B was presented too. This document is the final version that includes descriptions of all studied adaptations as well as simulation results. The Year 3 adaptations are marked as new. In addition, the D4.3 includes the AMC and HARQ techniques finally selected for the LOLA Solution Package.
- Task 4.4: Deliverable D4.4 Adaptive Modulation and Coding Scheme for Hybrid Analog/Digital Transmission v3.0 was generated during Year 3. This document is the final version of the deliverable and includes updates on the use of feedback and Simple Two-Way Protocols with Non-coherent Detection.
- Task 4.5: Deliverable D4.5 Scheduling Policies for M2M and Gaming Traffic v3.0 was generated during Year 3. As for the topology B, a baseline and cooperative broadcasting schemes was designed, implemented, simulated, and evaluated. This document is the final version of the deliverable and includes descriptions of new scheduling policies and simulation results for most of them. The Year 3 adaptations are marked as new. In addition, the D4.5 includes the traffic scheduling techniques finally selected for the LOLA Solution Package.

2.4.2 Contribution

Partners have contributed to WP4 according to the descriptions below.

1. **AT4** wireless was the lead-contractor for the WP and all the deliverables within Tasks 4.1, 4.2, 4.3 and 4.5. Activities carried out include:
   - Leading of technical discussions within WP4 through day-by-day e-mail communication and teleconferences (animation and minutes).
   - Preparation and presentation of the WP4 session in the 2nd Review Meeting at Brussels, Belgium, on March the 14th 2012.
   - Preparation and animation of the WP4 session in the 9th Project Meeting at Paris, France, from 24th to 25th of May 2012.
   - Preparation and animation of the WP4 session in the 10th Project Meeting at the Technical University of Vienna, Austria, on November 9th 2012.
   - Preparation and animation of the WP4 presentation in the M2M Workshop held at A1TA premises in Vienna, Austria, on November 8th 2012.
   - Edition of D4.3 v3.0 and D4.5 v3.0 with the cooperation of the other partners.
   - Technical contribution to D4.3 related to Topology A, including descriptions of new adaptations (CoMP Joint Processing at Transmission and Coordinated Multi-Cell Channel Coding), simulation results, analysis and conclusions.
   - Technical contribution to D4.5 related to Topology A, including descriptions of the new adaptations (latency-aware schedulers for LOLA applications, semi-persistent scheduling and adaptive MIMO transmission), simulation results, analysis and conclusions.
   - Contribution to the publication activities related to WP4 work.

2. **Thales** Communications and Security's main contributions are:
    - Active participation to teleconferences and meetings, in particular with respect to Topology B topics. Preparation of technical presentations for the meeting concerning Topology B.
    - Technical contribution to D4.3 related to the definition of the HARQ strategy that shall be used for inter-cluster communications in a mesh network based on LTE. The considered topology is a diamond topology, where some bridging Mesh Relays (MRs) which belongs at the same time to two adjacent clusters can cooperate (with distributed Alamouti and "Decode and Forward") for forwarding the messages between the two Cluster Heads (CHs). Support was provided for a link-level simulator which was built by the partner LiU and EURE on the OpenAirInterface (OAI). Simulations were done; results were analyzed and published in the final version of D4.3. The innovation of the work consists in the network topology without direct link between the source and the destination, which is far less studied in the literature than the one with the direct link, and above all, in the fact of proposing a HARQ strategy which can be implemented in the LTE standard. The LOLA solution package concerning Topology B was also described in D4.3 Release M36.
    - Technical contribution to D4.5 related to Topology B, about adaptations related to fast transmission of short and non-periodic signals (like alarms). During Y3, the study on cooperative broadcast and its comparison with the baseline technique were finalized. Simulations were done in Omnet++ and results analysed, compared and inserted in D4.5 Release M36. The specificity of the LOLA solutions for cooperative broadcast is that it takes into consideration a certain number of practical aspects related to the LTE standard. The LOLA solution package concerning Topology B was also described.
3. **Eurecom's** main contributions are:
    - sparse-traffic AMC in presence of interference (HetNet scenario) algorithms (D4.3) Improvement of upper and lower (distortion) bounds on achievable performance with multiple correlated sources and its performance evaluation (D4.4)
    - a protocol design for one-shot transmission of correlated sources (D4.4)
    - A packet aggregation method for random access (3GPP PRACH method) under latency constraints (D4.5).
    - DRX modelling and optimization (D4.5)
    - Develop a dynamic resource allocation for the CBA (random) resources (D4.5)
    - A TTI bundling scheme for random access enabling UE to send sends multiple preambles in one random access to increase the random access successful rate (D4.5)
    - Specification and performance evaluation of hybrid analog-digital transmission extensions (D4.4) for a two -round multi -source transmission protocol
    - Refinement of collaborative link establishment, MAC buffer, collaborative BSR, and scheduling at the clusterhead specification for mesh extensions to LTE access protocol stack
    - Development of system-level simulation platforms for the proposed AMC, packet aggregation, DRX, and TTI bundling together with the A/D transmission techniques in topology A
    - Development of system-level simulations for Topology B algorithm validation (distributed
    - AMC and Hybrid, ARQ and MAC buffer and scheduling)
4. **Linköping** University's main contributions are:
    - Design of advanced detection algorithms for improving the reliability of ACK/NACK messages transmission in PUCCH. The performance of the designed algorithms for the LTE uplink control channel in multiple-antenna setups has been investigated.

2.4.3 Significant Results

The main outputs derived from WP4 during Year 3 include:

- In the area of framing and low-layer signalling for topology A two techniques have been studied: slot-based decoding and contention-based random access. Both techniques provide latency gains in certain scenarios. Concerning topology B focused has been put on providing as clear as possible specifications of the redesign needed to adapt the PHY and MAC layers of the mesh system developed in CHORIST to the LTE PHY and MAC.
- In the area of AMC and HARQ for topology A two new techniques have been studied: CoMP Joint Processing at Transmission and Protection of ACK/NACK messages. Proper analysis has been performed to determine the conditions at which these techniques provide latency gains. As far as Topology B is concerned, a new HARQ procedure was jointly proposed by TCS, LiU and EURE for inter-cluster communications possibly with cooperation among the bridging MRs via a distributed Alamouti space-time code plus a Decode and Forward protocol. The technique is able to lower the latency of the transmissions between clusters, with respect to a reference situation with one MR. This gain is paid by a reduction of spectral efficiency in certain cases, due to some resource wastage in the first hop. This wastage is however necessary to make the system more robust in certain link configurations. Moreover, the algorithm is implemented in a distributed way (between the two CHs) and without needing an exchange of signalling between MRs. This technique is part of the LOLA solution package for Topology B. Five AMC and HARQ techniques were finally selected for the LOLA Solution Package: More robust MCS for retransmissions (topology A), Traffic load-aware AMC (topology A), Adaptive transmission power (topology A), AMC for sparse latency-constrained traffic (topology A) and HARQ for inter-cluster communications (topology B).
- In the area of traffic scheduling for topology A two new techniques have been studied: CoMP Partial Frequency Reuse (PFR) and Carrier Aggregation (CA) scheduling with co-existence between LTE and LTE-A users. Conditions at which these techniques provide latency reductions are identified. Concerning topology B, the final results of cooperative broadcast for fast transmission of short messages were provided and compared to the ones obtained with the baseline broadcast algorithm. The most relevant metrics have been shown e.g. the distribution of the maximum latency experienced in the network, the delivery ratio, and spectral efficiency. It was shown that the cooperative broadcast technique can provide, in certain configurations, significant latency gains (see D4.5 release M36 for more details). Three traffic scheduling techniques have been finally selected for the LOLA Solution Package: CoMP Partial frequency reuse (topology A), Contention-Based Access with resource allocation (topology A) and Broadcast transmission of short packets (topology B). In the area of hybrid analog/digital transmission, a Two-way low-latency feedback protocols aiming minimal distortion for single, dual sources has been developed. Lower bounds on the reconstruction error of arbitrary multi-sensor transmission strategies have been found for optimal multiple access and encoding strategies.

2.5 WP5 – Integration and Validation

LEADER: EURE

Partners: EURE, TUV, LIU, AT4, MTS

Start month: M12 **End month**: M36

2.5.1 Progress

WP5 activities span from M12 to M36 and are divided into 4 tasks, which are briefly presented hereafter:

- Task 5.1 testbed definitions, where a high level description of three testbeds is provided together with the validation scenarios highlighting fundamental objectives of LOLA.
- Task 5.2 Large-scale LTE-A emulation for M2M/Gaming, where end-to-end user-plane and control-plane latency seen by M2M/gaming applications are measured in a fully loaded dense network.
- Task 5.3 Selected LTE-A PHY/MAC enhancements end-to-end validation, where some low latency techniques will be tested against AT4W and EURE platforms
- Task 5.4 Validation of selected WP4 techniques on Rapidly-Deployable Mesh Demonstrator, where the selected low-latency transmission/relaying techniques will be integrated in LOLA testbed 3 in a multi-hop rapidly-deployable mesh configuration.

The objectives for each of the WP5 tasks are the following:

- Task 5.1 was scheduled within Year 1 with the objective of identifying the validation scenarios, hardware, and required techniques to fulfil the experimental objective of the project.
- Task 5.2 was scheduled to begin as of Year 2, and consists of releasing an emulation platform and methodology for large-scale system validation and means for performance evaluation.
- Task 5.3 was scheduled to begin as of Year 2, and pertains to the release of an implementation of the selected MAC/PHY techniques on AT4W and EURE platforms and the validation of latency reductions for M2M/gaming traffic.
- Task 5.4 was scheduled to begin as of Year 2, and targets to improve the existing CHORIST mesh platform with the selected low latency techniques and to validate the latency reduction in multi-hop scenarios.

Progress made during this period concerns

- Task 5.1: Not applicable.
- Task 5.2: Deliverable D5.3 “Validation Results for WP4 Algorithms on Testbed 1” was released during Year 3. It provides an overview of the testbed 1, implementation details, and the validation results on the WP3 M2M and online gaming traffic models and WP4 contention-based random access into the platform.
- Task 5.3: Deliverable D5.5 “Validation Results of WP4 Algorithms on Testbed 2” was generated during Year 3. It provides details about the integration campaign between the OAI UE and AT4 eNB as well as the evaluation results.
- Task 5.4: Deliverables D5.6 ”First report on Integration of WP4 Algorithms Testbed 3” and D5.7 “Validation Results of WP4 Algorithms and M2M Sensing Applications on Testbed 3“ were generated. D5.6 provides the specification of the mesh extensions to LTE access protocol stack and physical layer procedures. D5.7 presents the results of WP4 adaptation for the mesh topology in two stages: first it provides the results obtained from the inlab system validation platform, followed by the results of the field trial during the final review of the project.

2.5.2 Contribution

The partners have contributed according to the description below:

1. **Eurecom** is the lead contractor in WP5 and of all deliverables within tasks 5.1 and 5.2. In terms of contribution, Eurecom performed the following activities:
   - Specification and development of a full LTE/LTE-A MAC/PHY and its inlab system validation platform with supporting tools
   - Test campaigns against the AT4’s eNB and other UE implementations to validate the compliance of OpenairInteface implementation in both TDD and FDD formats

- Development of the simulation/emulation platform for multi-relay transmission to validate topology B protocols and algorithms
- Integration of mesh extensions on the OpenAirInterface SW/HW platform

2. **Thales** Communications and Security's main contributions are:
   - Participation to WP5 telcos, writing of minutes of the telcos, and discussions during plenary meeting, in relation to testbed 3 (mesh network demonstration). TCS lead the coordination of the software development efforts of the involved partners (TCS, EURE and LiU).
   - TCS was in charge of the edition of D5.6.
   - TCS contributed to D5.6 with the specifications of modifications of LTE at PHY, MAC, RRC layers for supporting part of the functionalities required by a wireless mesh network.
   - TCS contributed to the software development of testbed 3 on the OAI environment, with a specific focus on new RRC procedures, procedures for the initialisation of the virtual link at IP level, new MAC forwarding functionalities. It provided support to the other partners for the software development of the other MAC parts: queuing and buffering, scheduling control signalling. This work aims at integrating the inter-cluster communication capability based on virtual IP link with MAC forwarding and cooperation with distributed Alamouti, which has proposed in WP4.
3. **AT4** wireless main contributions are:
   - Upper layer developments on the TDD eNB emulator to overcome issues found during Year 2 (non-stable behaviour in UL IP data performance, Radio Link Control buffering issues when handling downlink IP data)
   - Test campaigns against the Eurecom's UE and other UE implementations to validate Year 3 developments in the AT4LP
   - Development of WP4 adaptations using the Software Development Kit (SDK) enabled during Year 2. These adaptations were integrated into the AT4 wireless eNB emulator and later evaluated against a number of UE implementations
   - Developments on the measurement tools enabled during Year 2 for IP performance measurements in test bed 2 (also shared with WP3 partners to allow for UDP one-way delay measurements)
   - Technical contributions to D5.5 compiling outputs from the abovementioned activities
   - Participation to teleconferences and meetings
4. **LiU** main contributions are
   - Development of synchronization, phy procedures, and collaborative transmission for the topology B
   - Validation of the collaborative transmission
   - Setting up the testbed
5. **TuV** main contribution
   - Validation of the traffic models in the openair traffic generator
   - Implementation of a generic M2M traffic generator tool in the openairinterface
   - Setting up the precise PC synchronization for accurate OWD measurements
   - Delay model for the mobile core networks
6. **MTS** main contribution
   - Several measurements following the D3.5 campaign, including tracing at different points in the network, in order to dissect the round trip time to portions belonging to different parts of the network (access, core, backbone), TCP and UDP measurements
   - Thorough analysis of traces and cell statistics from measurements
   - Analysis of real M2M deployment yielding same KPI degradation as in D3.5 measurements
   - Measurements, TCP and UDP, for proving server processing delay for the developed Traffic Generation application

- Preparation of several papers resulting from D5.3 measurements: Evaluation of the UTRAN (HSPA) performance in different configurations in the presence of M2M and Online Gaming traffic (submitted to Transactions on Emerging Telecommunications Technologies, Wiley), Latency analysis for M2M and Online Gaming traffic in an HSPA network with sufficient resources (in preparation, to be submitted to a journal).

2.5.3 Significant Results

The significant results were:

- In the area of LTE/LTE-A implementation, OpenAirInterface initiative offers to academia/industry the first compliant open-source SW/HW LTE protocol stack and PHY. This is extended with the selected adaption from WP4 and traffic models from WP3 available through the openair repository at https://svn.eurecom.fr/openair4G
- To facilitate the performance evaluation and development of new algorithms and protocols, a realistic large-scale in-lab system validation platform for LTE access stratum with supporting tool has been developed. To increase the scalability, the platform has been upgraded to support multi-core computing node architecture.
- The experimentations for the testbed 1 have been shown that the CBA latency reduction depends mainly on four parameters: traffic pattern, number of CBA group, backoff window, and LTE frame type and configuration, and that it can achieves a latency reduction by 30% (e.g. from 70ms to 50 ms). The latency performance increases as the traffic becomes more sparse, which validate that the scheme is more adapted to the sporadic traffic.
- For the LTE mesh extension (topology B), the required modifications to the existing LTE specification to support mesh topology has been updated and integrated within the platform. In addition, an emulator was developed which will be used in WP4 for HARQ/AMC experimentation. In particular, the procedures regarding MAC forwarding and cooperation between mesh relays (MRs) have been finished. The aim of the demonstrator is to show a virtual IP link between two cluster heads, letting MRs cooperate on packet forwarding to enhance inter-cluster communications. This work was done in joint cooperation between EURE, TCS and LiU.
- The experimentations in testbed 3 have shown that the there is latency gain of 10% without any loss in the average throughput in transmitting a packet through a virtual link in the most unfavorable conditions (lower bound). This proves that collaborative transmission and MAC forwarding through a virtual link can significantly improve the latency in the mesh topology. This is also applicable to LTE-A, where relay nodes are transmitting to the UE. The conclusion is that there is delay-throughput trade-off between the L3 relaying and L2 relaying in LTE-A.
- Development of link simulator based on the OpenAirInterface for multi-relay collaborative transmissions in topology B testbed.
- As for testbed 2, significant progress was made on the integration of Eurecom's UE implementation and the AT4 wireless eNB emulator. The WP4 technique titled "more robust MCS for retransmissions" was successfully integrated and evaluated in the test bed.
- Through measurements in a live network, identification and verification of the relation between packet size and inter-arrival time on one hand, and latency on the other.
- Through measurements in a live network and through real massive M2M application deployment, identification of main KPIs affected, as well as secondary KPIs that could serve for the assessment of Node B load (relative to its resources and the number of machine users) and ability to provide required latency (journal paper)
- Latency per different parts of the Telekom Srbija HSPA network and backbone.

2.6 WP6 – Dissemination and Standardization Activities

LEADER: LIU

Partners: EURE, TUV, LIU, AT4, EYU, MTS

Start month: M1 **End month**: M36

2.6.1 Progress

Activities of WP6 span from M1 to M36 and is divided into 4 tasks, which are briefly presented hereafter:

- Task 6.1 concerns the publication of papers in international journals and conferences.
- Task 6.2 defines the creation and maintenance of the project webpage.
- Task 6.3 concerns the organizing of a project related workshop in M33.
- Task 6.4 relates to the project activities towards standardization.

Progress made during this period involves:

- Task 6.1 The LOLA consortium has been presented at the Future Network & Mobile Summit. Additional poster presentations and demonstrations of the project results has been made at 7 more occasions. A total of 34 publications has been submitted, accepted or published during the last year of the project. Developed software applications have been publicly available.
- Task 6.2: The project's webpage has been updated with the latest information about the project results. The submitted deliverables has been uploaded in the private area. The publications have been made accessible through the public area of the website.
- Task 6.3: Instead of a single workshop, three Special Sessions at different conferences has been held during the period. A forth Special session has been organized and will be held at the ICC in June, 2013.
- Task 6.4: A total of 3 text submissions were accepted within 3GPP groups during Year 3: LTE RAN Enhancements for Diverse Data Applications Working Group (2 contributions) and the Enhancement of Minimization of Drive Tests for E-UTRAN and UTRAN Working Group (1 contribution).

2.6.2 Contribution

The partners have contributed according to the description below:

1. **Linköping** University is the lead-contractor for WP6. The main contributions during the period are the following:
    - Organized WP6 tele-conferences.
    - Contribution to, update, and finalization of deliverable D6.2.
    - Organization of the LOLA Special Session at EUSIPCO 2012.
    - Contributions to scientific dissemination in form of conference and journal papers.
    - Maintenance of the LOLA website

2. **Thales** Communications and Security's main contributions are:
    - Participation to WP6 tele conferences and meetings.
    - Contribution to D6.2.
    - Writing and presentation of a paper on the comparison of performance between a baseline broadcast strategy and a cooperative broadcast strategy at the conference ISCWS 2012, Paris, August 28th-31st, France.
    - Writing and presentation of a paper on the HARQ strategy for inter-cluster communications for wireless mesh networks based on LTE at the conference EUSIPCO 2012, August 27th-31st, Bucharest, Romania.

- Participation at two workshops on digital communications, without presentations: workshop of the MOKAMIMODYN project Lille, France, 20/03/2012 on communications for PMR (trains systems); and Workshop on Information Theory and Coding for Cooperative Networks Paris, France, 27/03/2012 on wireless networks using cooperative communications.
- Participation at the LOLA Workshop in Vienna, Austria, 08/11/2012, with the presence of stakeholders (A1) and presentation of WP4 results on Topology B.
- Participation to a Winter School on OpenAirInterface, Sophia Antipolis, France, 19-22/02/1012, learning session for favouring WP5 development of testbed 3.

3. **Eurecom's** main contributions are:
    - Contribution to D6.2
    - Contributions to scientific dissemination in form of conference and journal papers
    - Contribution to the RAS cluster meetings
    - Promote the results of the project, in particular to the users and stakeholdets
    - Present a common booth with ICT FP7 Samurai Project for IST Summit in Germany presenting the innovations from the LOLA project
    - Organizing workshop/conference on simulation/emulation tools to demonstrate the WP5 achievement related to the testbed 1
4. **TuV** contributions are
    - Participation to WP6 tele conferences and meetings.
    - Contributions to scientific dissemination in form of conference papers, journal publications and book chapters.
    - Co-Organize special session on LTE-A on ICC 2013.
    - Organize an Industrial Workshop in Vienna.
    - Put code generated in Lola under Open Source
5. **AT4's** main contributions are:
    - Circulation of the interim document "Study of 3GPP Work Items", periodically updated every 3 months
    - Dissemination of project general information at the AT4 wireless web site (http://www.at4wireless.com/corporate/rd-activities/lola.html)
    - Active tracking of 3GPP activities based on the plan for standardization activities developed during Year 2
    - Contribution to the WI RAN Enhancements for Diverse Data Applications. The output was the resource R2-122512 containing the summary of e-mail discussion [77bis#25] on LTE assistance information. The input provides views on whether assistance information is seen beneficial for network signalling load, resource handling and UE battery consumption, and why..
    - Contribution to the WI RAN Enhancements for Diverse Data Applications. The output was compiled in the resource R2-122251 containing the summary of e-mail discussion [77bis#26] on L1 uplink control signalling. The input describes a proposal to use the RACH to send some real-time data that requires short latency that cannot be achieved by the existing LTE UL access method.
    - Contribution to the WI RAN 3.2.5.2. Enhancement of Minimization of Drive Tests for E-UTRAN and UTRAN. The output was compiled in the resource R2-122157 containing the summary of e-mail discussion [77bis#21] on scheduled IP Throughput measurement scope. Inputs provide views on whether IP throughput measurements should be performed per RAB, per QCI, or per UE following same directions as in LOLA WP4 and WP5.

- Presentation of the article titled "Evaluation of Latency-Aware Scheduling Techniques for M2M Traffic over LTE" in the EUSIPCO 2012 Conference held in Bucharest (Romania) in August 2012.
- Submission of the article titled "Performance Evaluation of cooperation-based techniques for M2M traffic over LTE" in the PIMRC 2013 to be held in London (UK) on September 2013.

6. **EYU** main contributions are:
    - Participation at the LOLA Workshop in Vienna, Austria, 08/11/2012
    - Organization of a special session on M2M at the WONS'12 in January 2012 with a paper published
    - Organization of a special session on M2M (Machine-to-Machine) and IoT (Internet of Things) Evolution at Telfor 2012
    - Contribute to LOLA standardization plan
    - Organization of a summer school together with the FP7 projects EXALTED, SmartSantander, HOBNET and IOT-6. The summer school was held during the period 3-7 September 2012 in Mecavnik, Serbia
    - Contributions to scientific dissemination in form of conference papers and journal papers, presentations and book chapters:
        - Presentation of a paper at WONS 2012
        - Presentation at 6th KuVS Workshop in Berlin
        - Presentation of a paper for esIoT 2012
        - Presentation of a paper for Telfor 2012
        - Preparation of two journal papers (one submitted in ETT, Transactions on Emerging Telecommunications Technologies) and another conference paper
        - Book chapter in "Machine-To-Machine Communications - Architectures, Technology, Standards, and Applications"
7. **MTS** main contributions are
    - Contributions to scientific dissemination in form of conference and journal papers, presentations:
        - Presentation of a paper at WONS 2012
        - Presentation at 6th KuVS Workshop in Berlin
        - Preparation of a paper for esIoT 2012
        - Invited presentation at Fraunhofer FOKUS FUSECO Forum
        - Preparation of a paper for Telfor 2012
        - Project presentation at Telfor 2012
        - Preparation of two journal papers (one submitted) and another conference paper

2.6.3 Significant Results

The significant results were:

- Contributions to the 3GPP standardization process on the WI RAN Enhancements for Diverse Data Applications and the Minimization of Drive Tests working groups
- Significant scientific dissemination activities in form of conference and journal papers.
- Organizing three Special Sessions at WONS 2012, EUSIPCO 2012 and TELFOR 2012. Preparation of a Special Session at ICC 2013.
- Involve the potential users and stakeholders outside of the consortium, namely A1 operator Austria, Orange-labs France, LTE platform providers Com4innov.
- Presentation of the LOLA project results at various forums.
- Dissemination of the opensource software applications developed within the project

2.7 Summary of the use of resources per WP and per beneficiary during year 3

Partner			WP1	WP2	WP3	WP4	WP5	WP6	Total PM
1	EUR	Total effort scheduled	12	1.65	13	24	39.35	3	93
		Work during the period	4.49	0	5.67	20.3	18.66	2.34	51.46
		Total work	11.76	1.65	12.91	36	45.45	4.24	112.01
2	TCF	Total effort scheduled	0	6	0	28	15	2	51
		Work during the period		0	0	8.26	14.74	1	24
		Total work		6	0	27.66	19.64	2.1	55.4
3	TUV	Total effort scheduled	0	2.5	46	0	19	4.5	72
		Work during the period		0	8.7	0	15.9	1.9	26.5
		Total work		2.5	43.2	0	17.9	7.1	70.70
4	LIU	Total effort scheduled	0	4	0	31	19	6	60
		Work during the period		0	0.5	3.40	8.2	3.35	15.45
		Total work		4	0.5	32.9	17.65	7.85	62.9
5	AT4	Total effort scheduled	0	4	0	31	29	6	70
		Work during the period		0	0	7.2	12.6	2.2	22
		Total work		4.2	0	34.6	26.9	5.7	71.4
6	EYU	Total effort scheduled	0	6	17	0	0	2	24
		Work during the period		0	2.05	0	0	0.7	2.75
		Total work		6	15.65	0	0	2.85	24.5
7	MTS	Total effort scheduled		5	21	0	6	2	34
		Work during the period		5.91		0	7.08	0.85	13.84
		Total work		5	21.8	0	7.46	2.66	36.92
Total scheduled for the consortium			12	28.15	97	114	127.35	25.5	404
Total work during the period			4.49	0	22.83	41.56	75.18	12.34	156.4
Total work during the project			11.76	29.35	94.06	131.16	135	32.5	433.83

3 Deliverables and Milestones Tables

Deliverables (excluding the periodic and final reports)

TABLE 1. DELIVERABLES[5]

Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I (proj month)	Delivered Yes/No	Actual / Forecast delivery date	Comments
D3.6	QoS metrics for M2M and Online Gaming	WP3	TuV	R	PU	M36	YES	1/03/2013	
D4.3	Adaptive Modulation and Coding Scheme and Hybrid ARQ Mechanism	WP4	AT4	R	RE/PU	M36	Yes	1/03/2013	
D4.4	Adaptive Modulation and Coding Scheme for Hybrid analog /Digital Transmission	WP4	AT4	R	PU	M36	Yes	1/03/2013	
D4.5	Scheduling Policies for M2M and Gaming Traffic	WP4	AT4	R	RE/PU	M36	Yes	1/03/2013	
D5.3	Validation Results for WP4 Algorithms on Testbed 1	WP5	EURE	R	PU	M39	Yes	1/03/2013	

[5] For Security Projects the template for the deliverables list in Annex A1 has to be used.

D5.5	Validation Results of WP4 Algorithms on Testbed 2	WP5	EURE	R	RE/PU	M39	Yes	1/06/2013	
D5.6	First report on Integration of WP4 Algorithms Testbed 3	WP5	EURE	R	PU	M28	Yes	1/06/2012	
D5.7	Validation Results of WP4 Algorithms on Testbed 3	WP5	EURE	R	PU	M39	Yes	1/06/2013	
D6.2	Overview of Scientific publications	WP6	LiU	R	PU	M39	Yes	1/06/2013	

Milestones

TABLE 2. MILESTONES							
Milestone no.	Milestone name	Work package no	Lead beneficiary	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments

MS13	Second Release of PHY/MAC algorithms for topology B in WP5	WP4	AT4	M28	YES	29/06/2012	Delivery of the D5.6
MS14	Optimized Traffic Model for WP5	WP3	TuV	M32	Yes	29/06/2012	
MS15	Final Release of PHY/MAC algorithms for WP5	WP4	AT4	M36	Yes	01/03/2013	
MS16	Validation results from Testbeds 1,2,3	WP5	EURE	M39	YES	1/06/2013	Results for the testbed 3 will be finalized after the field trial

4 Project Management

4.1 Management

4.2 Internal Communication

4.2.1 Communication means

Mailing lists, a cooperative platform and project website have been used efficiently for internal communication to provide:

- Team organization and workpackage work
- Document sharing services safely across the web

Emails and BSCW CMS are the main means to communicate between partners. Conference calls and the WebEx tool have been widely used for technical discussions among the WPs during this Period.

4.2.2 Consortium meeting

During the period, three meetings have been organized:

The 1st meeting was held at Brussels, Belgium, prior to review meeting on 14 March 2012. The meeting allowed

- Update on administrative issues and project schedule
- review the progress in each WP
- review the deliverables issued at M24

The participants were:

Name	Organization
Raymond knopp	Eurecom
Navid Nikaein	Eurecom
Antonio Cipriano	Thales Communications and Security
Eric Larsson	Linköping University
Dejan Drajic	Ericsson
Svoboda Philipp	TuV
Janie Baños	AT4W
Manuel Garcia Fuertes	AT4W
Milica Popovic	MTS

The 2nd meeting was held in Paris, France, on 24-25 of May 2012 and was hosted by Thales communication and Security. The meeting allowed

- To review project administrative issues in the project
- Present the current status of the project
- Process the outcome of the second review and identify the action points for each partners
    - Website
    - Journal publications
    - Involve users/stakeholders
    - Exploitation plan
- dedicated technical meeting on WP3 and WP4

- Summary of the WP3 and WP4 achievement and results
- Planning for the WP5 integrations and validation testbeds
- Set the WP6 objectives including standardization plan
- Measure the work progress for each WP and refine the interactions between WPs

The participates to this meeting were

Name	Organization
Navid Nikaein	Eurecom
Tania Villa	Eurecom
Antonio Cipriano	Thales Communications and Security
Danyo Danev	Linköping University
Dejan Drajic	Ericsson
Philipp Svoboda	TuV
Manuel Garcia Fuertes	AT4W
Milica Popović	MTS

The 3ed meeting was held at TuV, Vienna, Austria, on 8 and 9 of November 2011. This meeting allowed :

- Revisit project administrative issues and planning for yearly review
- Present the WP6 achievement and workplan
- Present the WP5 status and workplan towards the three testbeds
- Coordination of the achievements across WPs and promote interactions
- Separate technical meeting on WP3 and WP4
- Measure the work progress for each WP
- WP3 and WP4 planning for review
- 1-day Workshop at A1 Telecom operator at Vienna to present the LOLA project results and discuss about the M2M and LTE

The participants were

Name	Organization
Raymond knopp	Eurecom
Navid Nikaein	Eurecom
Antonio Cipriano	Thales Communications and Security
Anton Blad	Linköping University
Danyo Danev	Linköping University
Philipp Svoboda	TuV
Markus Laner	TuV
Markus Rupp	TuV
Milica Popović	MTS
Manuel Garcia Fuertes	AT4W
Dejan Drajic	Ericsson

4.2.3 WP dedicated meeting

In addition to the consortium meetings, technical phone meetings for WP3, WP4, and WP5 led by AT4W, TuV, and EURE were organized during this period in order to address specific technical topics or coordination on deliverables.

Few ad hoc meetings were also organized during this perioid:

1. EURE and AT4 at AT4 premises for the integration of the testbed 2
2. EURE and TuV at EURECOM premises for the integration and validation of the WP3 traffic models for the testbed 1
3. EURE and LiU at EURECOM for the integration of the synchronization and collaborative transmission for the testbed 3 (mesh topology)
4. EURE and TCS at EURE for the integration of collaborative link establishement, MAC buffer, scheduling for the testbed 3.

4.3 Status on project planning

The project is globally in line with the initial schedule described in the Annex I, in terms of work progress, deliverables and milestones. Regarding the delivery of the deliverables, 2 months delays were experienced without any deviations from the objectives.

Del No.	Del. Name	WP#	Data	Latency
5.6	First report on Integration of WP4 Algorithms Testbed 3	WP4	M28	59 days
3.6	QoS metrics for M2M and Online Gaming	WP3	M36	60 days
4.3	Adaptive Modulation and Coding Scheme and Hybrid ARQ Mechanism	WP4	M24	60 days
4.4	Adaptive Modulation and Coding Scheme for Hybrid Analog/Digital Transmission	WP4	M24	60 days
4.5	Scheduling Policies for M2M and Gaming Traffic	WP4	M24	60 days
5.3	Validation Results for WP4 Algorithms on Testbed 1	WP5	M39	60 days
5.5	Validation Results of WP4 Algorithms on Testbed 2	WP5	M39	60 days
5.7	Validation Results of WP4 Algorithms and M2M Sensing Applications on Testbed 3	WP5	M39	60 days

5 Explanation of the use of resources

A copy of the explanation of the use of resources obtained through NEF is attached to this file.

6 Financial Statement – Form C and Summary Financial Report

A copy of the financial statement obtained through NEF is attached to this file.

7 Certificate

If applicable, a copy of the certificate will be attached to this file.

8 Publication in Year 3

[1] K. Zhou, N. Nikaein, and T. Spyropoulos, "LTE/LTE-A discontinuous reception modeling for machine type communications," Wireless Communications Letters, IEEE, vol. 2, no. 1, pp. 102– 105, 2013.

[2] P. Svoboda, M. Laner, J. Fabini, M. Rupp, and F. Ricciato, "Packet delay measurements in reactive IP networks," Instrumentation Measurement Magazine, IEEE, vol. 15, no. 6, pp. 36–44, 2012.

[3] R. Villa, T. Knopp and R. Merz, "Mathematical framework for dynamic resource allocation in LTE heterogeneous networks," IEEE Journal on Selected Areas in Communications: Cognitive Radio Series, 2012. Submitted.

[4] M. Popovic, D. Drajic, and S. Krco, "Evaluation of the UTRAN (HSPA) performance in different configurations in the presence ofM2M and online gaming traffic," ETT, Transactions on Emerging Telecommunications Technologies, 2012. Submitted.

[5] Y. Wu, D. Danev, and E. Larsson, "Improved detection of ACK/NACK messages in the LTE uplink control channel," in Vehicular Technology Conference (VTC Spring), 2012 IEEE 75th, pp. 1–5, 2012.

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