



PROJECT FINAL REPORT

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4.1 Final publishable summary report

Executive summary

A few years back, people thought of Space Internetworking as a decorative approach to space missions. Space Internetworking, however, constitutes a vital solution for future communications – the term reflects the mutual technological influence of Space into Internet and Internet into Space.

Given the amount of smart mobile devices currently available worldwide, along with the possibility of small satellites to offer Internet services in the future, space can enable the widest capability to interconnect people and devices in human history. And, in a sense, this can happen based on context, location, or other criteria adjusted to social or business policies. But, the ability to apply the power of Internet technology in support of space flight operations – in Earth orbit, at the Moon, and even in deep space – is now at hand as well. The design of more complex and productive joint space flight missions in the future is made possible through resource sharing, dynamic routing and network interoperability – that is, internet technologies are gradually incorporated into space as well.

By and large, an infrastructure for universal interconnection among humans and their artefacts is emerging. That infrastructure will unify internetworking and space flight technologies. A wide variety of innovations and applications will benefit from space internetworking: (i) space missions can reach deep space because resource sharing among different agencies enables more paths towards the destination - and far destinations will be reached (ii) space data will not be wasted, but instead it will be exploited and disseminated to interested users – this is not happening efficiently today, (iii) social policies will be deployed – space can support global, low-cost or free access to Internet and therefore, space can support global access to knowledge.

Having realised the research potential of Space Internetworking early on, we decided to highlight its benefits, detail a research plan and seek European support for the first European Space Internetworking Center: SPICE. Space Internetworking Center (SPICE) was founded in Xanthi, Greece, on September 1st 2010. Its establishment and operation was funded by the European FP-7 Capacities "Research Potential" program. Scientific and Project coordinator is Vassilis Tsaoussidis, Director of Internetworked Systems Lab and Professor at the Department of Electrical and Computer Engineering of the Democritus University of Thrace.

The main research goals of Space Internetworking Center are:

1. The design of space protocols that dynamically adapt to topology changes and communications anomalies, achieving high-rate of data transmission, even in deep-space missions.
2. The interoperability between different communication protocols, e.g. protocols used by ESA and NASA.
3. The dynamic and optimised dissemination of space data to interested institutes and organisations.
4. The utilisation of space communications for terrestrial applications, e.g. emergency situations.
5. The unification of space and terrestrial internetworking communications.
6. The deployment of delay tolerant networking for the benefit of terrestrial applications such as energy-saving architectures, social networking, etc.

Through SPICE project, Space Internetworking Center has become a center of excellence in the region of Thrace, the first of its kind in Europe.

Summary description of project context and objectives

SPICE project is based on four major pillars: exchange of know-how, upgrade of the existing facilities and the DTN testbed, research outcomes and knowledge dissemination.

Exchange of know-how

Since its establishment, SPICE has recruited top qualified researchers in the field of space internetworking and peripheral areas both as personnel and visiting researchers. Moreover, SPICE researchers had the opportunity to visit and work at cooperating organisations and universities such as ESA, NASA and the University of Cambridge. In particular, we have been cooperating with the European Space Agency on identifying ways to extend Internet into Space, we develop frameworks for space communications together with NASA and we are working with the University of Cambridge on providing Global Internet Access to all. Lectures from well-known scientists were also organised regularly at the premises of SPICE.

Facilities and state-of-the-art DTN testbed

SPICE facilities have been updated and are now separated into two buildings; a large space of 200 square meters in a newly built building in DUTH campus and a space of 100 square meters in the building where all laboratories of the department of Electrical and Computer Engineering of DUTH are located in the city center of Xanthi. The former space is divided into four offices, a meeting room and a presentation room, in order to fully support the needs of the Space Internetworking Center. The latter space is divided into three rooms; that is a laboratory, a dedicated room for the DTN testbed and an office reserved for visiting researchers.

SPICE DTN testbed has been enhanced with more components and specialised software and hardware and has become a prototype DTN testbed able to accurately emulate space communications. The upgraded DTN testbed is now used both for the evaluation of new space internetworking protocols and mechanisms and the participation of SPICE in joint research efforts on DTN with top universities and research institutes worldwide.

Research achievements

Several protocols and mechanisms have been developed using the upgraded SPICE DTN testbed. DTPC protocol extends DTN architecture in order to provide services similar to those offered by the transport protocols of the Internet, like TCP, Bundle Streaming Service allows for a smoother near real-time viewing experience of streaming data, originating from Space, and Bundle Delivery Time Estimation tool enhances Contact Graph Routing functionality with the calculation of queueing delays in forwarding decisions. Part of our software has also been incorporated in the latest DTN implementations that are being standardized by the Consultative Committee for Space Data Systems.

Knowledge dissemination

In order to spread and disseminate the acquired knowledge, SPICE has coordinated several activities during the past years. Research results have been published in top conferences and scientific journals, SPICE achievements have been presented to collaborating universities and institutes and workshops on delay-tolerant networking have been organised. Moreover, SPICE website is constantly updated and SPICE achievements are summarized in the tri-annual SPICE Update newsletter.

All SPICE achievements and events are disseminated by the constantly updated SPICE website: <http://www.spice-center.org>

There were three major objectives for SPICE project:

1. To develop a state-of-the-art Space Internetworking Center in Xanthi, Greece.

The key activities for the development of a state-of-the-art Space Internetworking Center include the improvement of the existing R&D infrastructure and the increase in the group's know-how.

The R&D infrastructure has been improved in terms of workstations, servers and networking equipment, as well as the enhancement of the DTN testbed with more components (e.g. stationary and mobile DTN nodes) and extra functionalities. The incorporation of ESA's Portable Satellite Simulator (PSS) and CORTEX CRT system allow for the accurate emulation of space link protocols (TM/TC), creating a platform to evaluate newly developed protocols that emulated the whole space communications protocol stack. Moreover, Satellite Tool Kit software provides exact information on planet movement and space weather conditions as input to the DTN testbed, in order to define real evaluation scenarios.

The increase in know-how has been achieved through the recruitment of top researchers in the field of networking and the mobility of SPICE researchers to collaborating institutes. Recruited researchers at SPICE have experience in peripheral topics to space communications and DTN and, thus, help extend SPICE research agenda. As far as the mobility of SPICE researchers is concerned, five SPICE researchers were mobilized to Jet Propulsion Laboratory (NASA, USA), AALTO University (Finland), ESA's European Space Operation Center (ESA/ESOC, Germany), IMDEA Networks Institute (Spain) and University of Cambridge (United Kingdom), in order to work on perform joint research in novel concepts.

Moreover, a Distinguished Speaker Series with international researchers as speakers was organised regularly. Several events were organised at the premises of SPICE that attracted the interest of the community of the region.

2. To develop strategic partnerships with other research institutes and increase the capacity of Thrace region in terms of quality and quantity.

The utmost goal of SPICE project was to achieve strong collaboration with research centers worldwide, actively participate in joint research projects and consult future space missions. In this context, one of the key objectives was to increase the visibility of SPICE and disseminate its research achievements. Several presentations to top research institutes worldwide, such as the Massachusetts Institute of Technology (MIT), NATO's Underwater Research Center (NURC) and Tampere University of Technology, took place during SPICE project, in an effort to promote SPICE research achievements and investigate possible areas of collaboration. At the same time, research results were presented to world-class conferences and workshops, while SPICE Project Coordinator actively participated in the regular meeting series that define the future standards in space communications. Collaboration with top institutes has led to SPICE participation in several ESA, FP7 and H2020 joint project proposals.

3. To develop new open source protocols and mechanisms for space internetworking that will be available through SPICE website.

Exploiting the new infrastructure, researchers of the Space Internetworking Center developed mechanisms and protocols for terrestrial and space delay tolerant networks. These protocols are open source and available through SPICE website. Providing open source software developed by SPICE researchers will significantly increase the visibility of Space Internetworking Center and its collaboration with other research institutes, SMEs and industry.

Description of the main S&T results/foregrounds

The utmost scope of SPICE as a center of excellence in Space Internetworking is to lead research community towards the most promising directions of research and development in the field of Delay Tolerant Networking (DTN) and Space Internetworking in general. SPICE incorporates Space and Internet technologies for their mutual benefit: Space benefits from Internet technologies and Internet benefits from Space communications.

To achieve that, SPICE project was based on four major pillars: exchange of know-how, upgrade of the existing facilities and the DTN testbed, research outcomes and knowledge dissemination. Hereby we detail the first three pillars.

Exchange of know-how

Through SPICE project, three senior researchers were recruited to enhance the research capacity of Space Internetworking Center. In particular, Dr Diego Borsetti and Dr Roman Dunaytsev received a contract of two years with SPICE, while Dr Eli Katsiri received a contract of one year.

Dr Borsetti has principally conducted research on Vehicular Ad-Hoc Networks at SPICE; his research has been focused on the study of geographic routing algorithms with a particular emphasis on the definition of optimal Road Side Units (RSUs) deployment strategies. Diego Borsetti also worked closely with junior researcher Olga Papadopoulou on the accuracy of neighbor location table in VANETs. The research activity was focused on the investigation and the evaluation of a cross-layer strategy based on a predictive algorithm and aimed at enriching the information contained in the location table of each vehicle. Dr Borsetti focused on terrestrial disruptive networks and the applicability of DTN in such environments.

Dr Dunaytsev studied the best practices and approaches developed to deal with the ever-growing P2P file sharing traffic. This led to a journal paper providing a comprehensive survey of P2P traffic management solutions. His research also focused on ISP interconnection and traffic exchange in the Internet. In parallel, Dr Dunaytsev studied deep space communications and delay-tolerant networking and worked on two relevant research papers; the former is dedicated to analytical modeling of data routing and forwarding in delay-tolerant networks, while the latter is focused on performance evaluation of erasure coding and HARQ-based schemes over deep space links.

The research agenda of Dr Katsiri aimed to (a) investigate the research issues involved in the Delay-Tolerant Cloud, (b) to define and analyze its requirements and (c) to draft a research plan for realizing the above vision. In particular, Dr Katsiri investigated *Cirrus*, a generalized cloud-computing framework, for creating and deploying real-time, stream processing applications, on demand. A research paper, “Cirrus: A Delay-Tolerant Cloud”, was submitted to WWIC 2012 conference and, after acceptance, was published in the proceedings. Moreover, a research proposal called “Cirrus: A Pervasive, Delay-Tolerant Cloud” was submitted for funding to NSRF’s “Research Excellence” (Aristeia) 2012 call.

Apart from the permanent researchers, SPICE has also accommodated five visiting researchers. In particular:

- Dr Artemios Voyatzis, associate researcher at the Industrial Systems Institute, Patra, Greece, visited SPICE for the time period of one month;
- Carlos Anastasiades, MSc, researcher at the University of Bern, Switzerland, visited SPICE for two weeks;

- Francesco Belli, software and systems engineer at Telespazio VEGA UK, visited SPICE for one week;
- Dr Eiko Yoneki, an EPSRC research fellow at the Computer Laboratory of the University of Cambridge, visited SPICE for one week and
- Dr Ferdinando Villa, senior researchers in Basque Center for Climate Change, visited SPICE twice for a total of two weeks.

Six long research visits to collaborating institutes were organised by SPICE in an effort to enhance our collaborations and our research potential. In particular, one researcher visited NASA's Jet Propulsion Laboratory, two researchers visited ESA's European Space Operation Center, and three researchers visited AALTO University, IMDEA Networks and University of Cambridge, respectively.

Jet Propulsion Laboratory (JPL), NASA, Pasadena, California, US

The general objective of the visit was to investigate problems in Delay-Tolerant Networking (DTN), such as bandwidth sharing between real-time and deferred data flows. This investigation was carried out over the duration of ten weeks, covering a vast spectrum of theoretical and development issues. The end result of *Mr. Lenas's* visit was the development of Bundle Streaming Service (BSS), a framework, specifically designed for DTNs, that supports the delivery of streaming media via DTN bundles.

European Space Agency (ESA/ESOC), Darmstadt, Germany

Having established the first European Center on Space Internetworking the alignment of our research agenda with the plans of the European Commission and the European Space Agency on future space communications is of utmost important. Strong collaboration with ESA is essential for the viability of Space Internetworking Center. Due to the broad spectrum of research interests on space internetworking within SPICE group, it was decided that two researchers would visit ESA and follow different research agendas.

The general objective of *Mr. Diamantopoulos's* visit was to analyse and evaluate the performance of CFDP for EUCLID, a scheduled joint ESA-NASA mission. Even though ESA plans to use CFDP protocol on EUCLID mission, ESA researchers do not have any experience on CFDP. In this context, the performed analysis was of great importance to mission designers, in order to estimate parameters, such as the minimum pass time and the set-up of CFDP protocol. Indeed, this 12-week long partnership resulted in numerous useful suggestions regarding the set-up of the EUCLID telemetry system.

The research agenda of *Mr. Bezirgiannidis*, on the other hand, involved the METERON project. METERON (Multipurpose End-To-End Robotic Operations Network) is one of the most well known active DTN projects with strong funding and a consortium that includes ESA/ESOC, NASA, ROSKOSMOS, ESOC, Vega Telespazio, CU-Boulder and BUSOC. ESOC is responsible for the development of the applications and services for the METERON project, however the research team working on METERON was lacking a person with expertise and working experience on DTN.

AALTO University, Helsinki, Finland

SPICE staff member *Ioannis Komnios* was a visiting researcher at COMNET laboratory of School of Electrical Engineering, AALTO University, Espoo, Finland for 2,5 months. The scope of the visit was twofold:

1. To establish a common research agenda on DTN routing between SPICE and AALTO that will lead to cooperation and joint publications and
2. To define a research concept that targets the utilisation of DTN technology as an overlay

network to different technologies in an effort to interconnect different types of objects.

During his visit, Mr Komnios worked closely both with Prof. Jörg Ott on DTN research topics and Dr Jose Costa-Requena on the definition of a research concept on Enhanced Networking of In-situ Components.

IMDEA Networks, Madrid, Spain

SPICE staff member *Fani Tsapeli* visited the IMDEA Networks Research Institute, located in Madrid, Spain, for two months. The purpose of the visit was to establish collaboration between SPICE and IMDEA research institute on research issues related to potential applications of DTN in terrestrial environments. In particular, during this visit Ms. Tsapeli worked closely both with senior researcher Dr Sergey Gorinsky and with staff researcher Dr Pierre Francois, on the research topic of offloading cellular networks through delay tolerant networks.

University of Cambridge, Cambridge, UK

The general objective of *Prof. Tsaoussidis'* visit at the Computer Laboratory of University of Cambridge, UK, was to investigate common grounds of collaboration between SPICE and Computer Lab, especially in the fields of Less-Effort Service internetworking, internetworking with DTN and the integration of satellite and terrestrial communications. The issue of potential applications of DTN to energy-efficient networking and Green Internet was investigated as well.

An important asset to exchange knowledge and promote research is the organisation of regular lectures and presentations from external researchers. SPICE has organised a regular “Distinguished Speaker Series” at the premises of SPICE. The complete list of presentations can be found in: <http://www.spice-center.org/distinguished-speaker-series/>

A regular colloquium among SPICE researchers, also open to all interested parties, was organised regularly. The complete list of presentations can be found in: <http://www.spice-center.org/colloquia/>

Upgrade of the existing facilities and the DTN testbed

SPICE facilities are separated into two buildings; a large space of 200 square meters in a newly built building in DUTH campus and a space of 100 square meters in the building where all laboratories of the department of Electrical and Computer Engineering of DUTH are located in the city center of Xanthi. The former space is divided into four offices, a meeting room and a presentation room, in order to fully support the needs of the new Space Internetworking Center. The latter space is divided into three rooms; that is a laboratory, a dedicated room for the DTN testbed and an office reserved for visiting researchers.

Space Internetworking Center has the capacity to occupy 30 permanent researchers, as well as visiting researchers in a dedicated office. SPICE meeting room, having the capacity to host up to 15 people, can cover the needs of SPICE in cases of Steering Committee meetings, External Advisory Board meetings, teleconferences etc. Moreover, the presentation room has a capacity of 50 people and can be used for events, such as Distinguished Speaker Series and colloquia. Both rooms are equipped with the necessary equipment, such as projectors, and constitute suitable venues to host small-scale events (up to 50 participants), i.e. panel sessions and workshops. Wi-Fi Internet connection is available in the premises of the center.

SPICE DTN testbed has been enhanced with more nodes and specialised components that accurately emulate the functionality of typical ground stations, space links and satellites. Our aim is to build an experimental research environment for developing and evaluating a variety of new architectures and

protocols for space communications. In particular, SPICE testbed presents the following key features:

1. *Realistic emulation of space communications.* Unlike the majority of existing DTN testbeds, which focus on terrestrial delay-tolerant communications, SPICE testbed provides a realistic experimental environment for satellite and space communications, including real and flight-ready components. Indeed, specialised hardware and software components have been incorporated into the testbed, enabling the testing, evaluation and validation of implemented mechanisms and protocols. Furthermore, a link with a geostationary satellite, namely HellasSat 2, is utilised on demand, to provide real satellite link characteristics for experimental purposes.
2. *Compliance with typical equipment of major space agencies.* SPICE testbed incorporates typical components used by space agencies for the evaluation of protocols prior to mission launch. In particular, the Portable Satellite Simulator (PSS) was built in compliance with ESA's requirements, while CORTEX CRT is used by all major space agencies in their ground station facilities to support their missions. Finally, Satellite Tool Kit (STK) is employed by mission designers as a tool to calculate not only exact satellite trajectories and contact durations, but also detailed communication characteristics, and perform link-budget analysis.
3. *Interface provision for multiple underlying protocols.* SPICE testbed not only supports a variety of convergence layers for underlying protocols that comply with CCSDS standards and major space agencies, but also facilitates the development of novel routing, transport, and management schemes. Taking advantage of this functionality, SPICE researchers are able to validate such schemes against standardized protocols and perform interoperability testing.
4. *Scalability.* SPICE testbed includes numerous nodes for the evaluation of complex communication scenarios that involve several space assets and can be further enhanced with virtual nodes installed on a high-performance server. Therefore, complex scenarios involving constellations of satellites (e.g., cubesats) and several end-users can be realistically modeled. It should also be mentioned that this scalability comes without adding any complexity, since the testbed is easily configured and controlled through dedicated workstations.

In detail, SPICE DTN testbed has been enhanced through SPICE project with:

- *15 emulation nodes*
The rack-mounted emulation nodes are powerful computational machines that can run several heavy-loaded experiments simultaneously. For this purpose, they are stored in a separate air-conditioned room, along with the majority of the testbed components.
- *20 mobile DTN nodes*
The mobile DTN nodes are used to emulate mobile nodes in the terrestrial DTN experiments. They comprise of laptops that run Unix-based operating systems and support the majority of available DTN implementations, as well as Maemo and Android mobile phones for the evaluation and experimentation of the corresponding DTN implementations, such as DTN2 and IBR-DTN.
- *Networking equipment (switches, firewall, router)*
The acquired networking equipment was used to interconnect the various components of the testbed, connect the testbed over the Internet and protect it from external attacks.
- *Space data storage devices*

The space data storage devices are used to extend the storage capabilities of the emulation nodes, in order to be used in future space data dissemination scenarios, since the amount of data obtained from space assets is expected to explode within the next few years.

- *Satellite communication equipment*
The satellite communication equipment, along with the satellite link, is used for experiments that include a link over Hellas Sat satellite to interconnect the testbed nodes located in Xanthi with the testbed node located at the premises of the Hellenic Aerospace Industry (HAI), near Athens. Prior to SPICE project, the required equipment had been borrowed from HAI.
- *ESA's Portable Satellite Simulator*
PSS has been integrated into the DTN testbed to represent the existing satellite links used by ESA. In particular, PSS supports telemetry protocol (TM) for the downlink and telecommand protocol (TC) for the uplink. It should be noted that ESA's Portable Satellite Simulator is the most effective way to evaluate the performance of a satellite protocol; once a protocol has been tested over PSS, it can automatically be applied to a real satellite link between a ground station and a satellite.
- *CORTEX CRT system*
CORTEX CRT-XL system allows a continuous improvement of the signal processing and the support of future standards through telemetry processing, CCSDS telecommand processing etc.
- *Satellite Tool Kit (STK)*
STK is off-the-shelf mission modelling and analysis software for space, defense and intelligence systems. The acquired license is for the Version 9.0 of STK Communications, STK Basic Edition, STK Integration Module and STK Professional Edition. STK is used to model complex systems (satellites, ground facilities), along with their sensors and communications, in the context of the mission environment. Through integrated visualization, STK brings a clear understanding of system behaviour and performance measured against mission objectives.
- *Sensors*
The purchased sensors are used in terrestrial DTN experiments, where environmental data are gathered from external sources in a delay-tolerant way (through data ferrying approaches). Such data can be combined with data coming from satellites, in order to provide new applications in several domains such as Earth Observation.

Research outcomes

Exploiting the new infrastructure, researchers of the Space Internetworking Center have developed several mechanisms and protocols for terrestrial and space delay-tolerant networks. Several of these protocols have been already incorporated in the latest Interplanetary Overlay Network (ION-DTN) release, and other are planned to be released in the following versions. Below we summarize our major contributions.

Bundle Streaming Service (BSS)

After several years of systematic research in various aspects of Delay/Disruptive Tolerant Networking (DTN) such as routing, transport protocols and convergence layers, DTN technology has reached a higher level of maturity. The development of a reliable set of working solutions and associated standards under the auspices of the Consultative Committee for Space Data Systems (CCSDS) and the Internet Research Task Force's DTN research group (DTNRG) has boosted the applicability of DTN architectures, which now present themselves as prominent solutions for global internetworking. Based on that progress, several studies promote the benefits of DTN architectures

and highly suggest their use in disruptive environments through the Bundle protocol, which encodes most functionality that an overlay network requires.

Our work deals with a relevant topic that has not yet seen much progress, despite its potential applicability: data streaming over DTNs. Data (and especially live) streaming in delay/disruptive tolerant environments becomes a particularly challenging task since the presence of high delays, frequent disruptions and variable bandwidth acts inevitably against the basic application principles of data streaming that call for mechanisms that guarantee smooth viewing experience of end-users.

In this context, we propose the Bundle Streaming Service (BSS) as a practical approach that addresses most of the networking challenges related to streaming over DTNs. BSS is a framework that enables “streaming” data to be conveyed via DTN “bundles” in a manner that supports in-order stream processing with minimal latency while still ensuring reliable delivery of all data to enable ad-hoc “playback” review of recently received information. Potential examples of real-time applications that could exploit the capabilities provided by this framework are one-way voice, video or continuous telemetry streaming.

The key concept behind BSS is to employ in the forwarding process of each DTN node both a best effort along with a reliable transfer protocol, in order to achieve minimal latency but also ensure reliable delivery of the whole stream. An additional advantage of our approach is that it does not confine future deployments of other sophisticated mechanisms on top of BSS, but instead, it grafts flexibility that further enhances synergistic application mechanisms. BSS consists of two basic components: a forwarder daemon and a library for building streaming-oriented applications.

BSS framework was developed as an extra module in JPL's Interplanetary Overlay Network (ION) software distribution that implements the DTN architecture. Following implementation, we conducted a preliminary experimental evaluation that aimed to establish the baseline performance characteristics of BSS over a simple streaming session under various network conditions, including variable propagation delays (PD) and high packet error rates (PER). The time needed for the complete reception of a stream consisting of 5000 frames was evaluated by using two basic sets of transport protocols in combination with BSS in order to evaluate its performance under terrestrial and Space environments.

The results obtained so far show that the suggested framework has the potential to improve stream reception in both terrestrial and Space environments, since it manages to reduce the total requested time of receiving 5000 frames by almost 80% in the worst case, when terrestrial protocols are in use while, in Space environments, where LTP “red” transmission is used in place of TCP, BSS achieves better results in cases where the error rate of the channel is above 10%.

Delay Tolerant Payload Conditioning (DTPC) protocol

The DTN architecture and the accompanying Bundle Protocol (BP) specification propose a means for data communication on potentially heterogeneous networks characterized by high propagation delays, frequent link disruptions and disconnections. Examples of such networks include deep-space networks, sensor-based networks, terrestrial wireless networks that cannot ordinarily maintain end-to-end connectivity, satellite networks with moderate delays and periodic connectivity, and underwater acoustic networks with moderate delays and frequent interruptions due to environmental factors.

Practically, BP constitutes a network layer responsible for source to destination bundle delivery, possibly over heterogeneous networks, which resides directly below applications. Thus, unlike the

traditional terrestrial protocol stack model, current DTN architecture does not include a transport layer for providing end-to-end services. Such services are left to the application. For example, in recognition of the potentially disconnected nature of DTNs, where an end-to-end closed-loop retransmission tactic is in most cases inefficient, retransmission of lost or corrupted data in the DTN architecture is performed only on a hop-by-hop basis, by the BP optional custody transfer mechanism, or convergence layer protocols. As a result, applications requiring typical end-to-end reliability must implement their own end-to-end message reliability mechanisms.

Even in these challenged environments where an end-to-end path may never exist, it is both possible and desirable to provide end-to-end transport services. In that context, the Delay Tolerant Payload Conditioning (DTPC) protocol was introduced. DTPC is a novel protocol that extends DTN architecture in a fashion that accords with the end-to-end principle. Being an end-to-end protocol, DTPC protocol needs to operate only at the endpoints of the communication system. DTPC protocol is an expandable, connectionless, reliable, sequenced transport protocol designed to be used on top of the BP offering the following services:

- **Controlled aggregation of application data units (ADUs) with application-specific elision**

In order to regulate the overhead introduced by BP protocol when large volumes of small ADUs are transmitted, DTPC protocol offers an aggregation service that aggregates ADUs, possibly from different applications residing in the same node, which have the same destination and require the same quality of service (class-of-service, custody transfer, etc.).

The aggregation service is controlled by two thresholds: a length threshold sets a maximum bound on the total size of aggregated ADUs and a time threshold prevents undue delay before transmission of data during periods of low activity. Additionally, the aggregation service is coupled with an optional elision service that enables applications to remove obsolete or redundant ADUs from aggregated data units before transmission, based on application-specific criteria.

- **End-to-end reliability**

DTPC protocol provides an additional degree of assurance in the delivery of application data when lower layer reliability mechanisms fail, by using an end-to-end ARQ mechanism that is based on positive acknowledgments. Retransmission timeout intervals are worst-case values based on data lifetime and limits on the number of retransmissions, rather than on round-trip-time estimations.

- **In-order delivery**

Each DTPC protocol data unit is uniquely identified by a sequence number, enabling delivery of the contained application data units in transmission order. Additionally, DTPC protocol offers a “latest delivery” service that allows for in-order delivery of application data with relaxed completeness constraints, such that holes in the receiving sequence are permitted as long as the missing data units are considered expired. This “latest delivery” service assures that out-of-order data units never get stranded or expire at the receiver waiting for the reception order to be restored.

- **Duplicate Suppression**

DTPC protocol suppresses the delivery of application data units (ADUs) that have already been received or that are considered expired, ensuring that duplicate ADUs are never received by an application.

Due to its flexible design, DTPC protocol can be easily adjusted to unforeseen usage scenarios. In that sense, DTPC protocol can be viewed as an application-independent framework for injecting end-to-end characteristics into the DTN architecture.

Bundle Delivery Time Estimation (BDTE) tool

In the Solar System Internet, coarse-grained estimation of the time of delivery of an application data item will not be trivial. The distances between communicating entities may be very large, measured in tens to thousands of light seconds, and may vary widely (e.g., Saturn is about six times further from the Sun than Mars is). Moreover, those distances are constantly changing as solar system objects follow their different orbital paths. In addition, since only precisely directed radiation can enable communication over such vast distances, the rotation of planetary bodies introduces additional latency by periodically making the reception of directed radiation impossible - interrupting communication altogether for some lengthy but predictable interval. In this context, such considerations render end-to-end data delivery latency not just lengthy but also somewhat challenging to predict: delay in conveying information about the communications state of an entity diminishes our confidence in the validity of this information when it finally arrives – and any failure of communication operations due to invalid information may impose yet more delay in communication.

Note that this already challenging problem statement presupposes successful communication whenever links are available. In reality the problem is much worse: data error rates are high in interplanetary communication by directed radiation, and any data loss may require retransmission. Retransmission may again require tens to thousands of seconds; and may itself fail and require further retransmission, resulting in unpredictable delivery latency.

By and large, a purely deterministic approach to predict bundle delivery latency in the SSI is rather scientifically naïve. Instead, an analysis of the likelihood for each bundle to follow some path, which incorporates both transmission latencies and retention latencies (contact interruption intervals) and considers the most plausible retransmission scenarios, allows for a weighted probabilistic delivery latency profile to be computed.

Our approach departs from this observation and introduces a novel method for estimating the bit error rate (BER) on each link. It uses recent network processing statistics to calculate the mean expected number of retransmissions on each segment of the end-to-end path and a binary search algorithm to estimate the expected BER. Network processing statistics will be supported by the DTN network management infrastructure.

Bundle Delivery Time Estimation (BDTE) is in essence an administrative network simulation tool that applies the CGR algorithm on every network node throughout the route of the bundle. The BDTE algorithm performs hop-by-hop simulations, provides possible arrival times for each hop, and continues iteratively through the entire predicted bundle route, ultimately resulting in the arrival time at the final destination. The calculated latency for each hop is based on deterministic and stochastic latency components. The former comprises propagation delay (also referred to as One-Way-Light-Time or OWLT) and transmission delay for bundle delivery (including overhead) via the link channel, i.e., the length of time that will be required simply to transmit the bundle given the maximum transmission rate on the link. The stochastic component is introduced by uncorrected channel errors, which compel packet retransmissions; it accounts for the propagation and transmission delay for retransmitted packets.

BDTE's computation is based on the fact that the deterministic components of the bundle's latency can be accurately calculated, whereas the stochastic latency can only be statistically predicted using each link's history observations. The result of this analysis is a link error rate forecast that provides several estimates of the number of transmission rounds that may be required for successful bundle delivery to the next node, each with its own probability. For each possible number of transmission rounds, a different delivery time to the next node is calculated. This time is then used as the transmission initiation time for the next hop of the route and a new simulation is then performed. This method continues consecutively to the final destination and ultimately results in a set of distinct bundle arrival times, with different probabilities that theoretically sum up to 100%.

DTN-Agent for NS2

SPICE researchers have implemented a DTN model as a set of classes in the ns-2 simulator. The model was developed in order to study the deployment of DTN on top of traditional, Internet-based networks and can be useful in experimenting with issues such as: storage space management, custody acceptance and rejection reporting, routing strategies, retransmission timeouts, and bundle fragmentation. The underlying network topology is assumed to be static and, thus, this model is inappropriate for testing routing algorithms in ad-hoc network settings, at least for the time being. Implementation of a full-fledged routing scheme is part of future development plans. The DTN model supports both TCP and UDP convergence layers.

The DtnAgent is implemented as a subclass of the Agent class and, in a fashion similar to other agents, can be attached to an ns-2 node as well as a source or a sink application. There is a single type of a DtnAgent and it is used for all purposes; as a source agent, a relaying agent, or a destination agent. When the TCP convergence layer is used a special pair of source and sink TCP classes is employed, while when the UDP convergence layer is used a customized UDP class is employed. These classes are named TcpDtnAgent, TcpDtnSink and UdpDtnAgent respectively and, by utilizing a newly introduced DtnHeader, work along with the DtnAgent in facilitating bundle transmission and reception.

Under the TCP convergence layer operation, both the DTN and the transport layers implement fragmentation/segmentation based on the maximum bundle size and the maximum packet size respectively. When the application orders the transmission of a certain amount of data (i.e. an ADU), this data is fragmented based on the maximum bundle size by the DtnAgent. Depending on the maximum bundle size and the amount of data, the whole ADU may be transmitted as a single bundle. The created bundles are passed on to the TcpDtnAgent where they are further segmented, creating the appropriate number of TCP packets. Each TCP packet contains the offset of the original bundle so that duplicate data reception originating from multiple sources can be identified. The TcpDtnAgent increments the packets available for transmission by the number of the newly arrived packets, and appends the corresponding DtnHeader to a list, along with some additional information (i.e. TCP sequence number). When the time comes to actually transmit a certain packet, a helper function retrieves the corresponding DtnHeader from the list and populates the DTN header of the outgoing packet. On the other end of the connection, the TcpDtnSink aggregates in-sequence, incoming data based on the bundle it belongs to, and delivers it along with the bundle header to the attached DtnAgent.

Under the UDP convergence layer operation, each bundle is encapsulated in a single UDP packet, with the packet size being set to the total bundle size (a UDP header is not considered in ns-2). If the bundle size, including the bundle header, is larger than the maximum packet size for UDP, bundle transmission is aborted. Unlike TCP, the UdpDtnAgent does not support flow control and, therefore, data created at the application layer and passed on to the DTN and then to the UDP layer are directly

buffered at the next hop link queue. Hence, if a file of 1 MB must be transferred, there must be at least 1 MB of space at the queue of the outgoing link to the next hop, or else part of the data will be dropped at the very node that it was produced.

As of now, routing is implemented in a simplistic way, assuming a convenient rhombus topology. When a source DtnAgent is connected to a destination DtnAgent the destination agent is added to the source agent's downstream (outgoing) connections, while the source agent is added to the destination agent's upstream (incoming) connections. Each connection requires two sets of a TcpDtnAgent and a TcpDtnSink, or two sets of two UdpDtnAgent classes for the UDP convergence layer case, in order to accommodate data bundles in the downstream direction and report bundles in the upstream direction. In a DTN overlay each DtnAgent can have multiple incoming and multiple outgoing connections as long as all outgoing connections ultimately lead to the final destination. The final destination is regarded as the DtnAgent that is attached to a sink application. All other DtnAgents on the path simply forward the incoming bundles on to their outgoing connections in a round-robin fashion, following a cut-through strategy (an incoming packetload of a bundle is immediately passed on to the next downstream TcpDtnAgent or UdpDtnAgent). Along these lines, alternative mechanisms of outgoing connection selection as well as non cut-through routing (a bundle is fully received before being forwarded) can be easily realized.

The DtnAgent implements a simple custody acceptance/rejection and retransmission mechanism, targeted mainly towards accommodating certain experimental scenarios. However, other schemes can be readily implemented and incorporated into the existing code. Each DtnAgent is assumed to have a certain amount of available storage space. When the first bytes of a new bundle arrive (i.e. those that contain the bundle header in a real-world situation), the agent checks if accepting the bundle will exceed the available storage space. In this case it initiates a custody rejection report to the upstream agent and rejects subsequent bytes belonging to the same bundle. If adequate storage space is available, the bundle is accepted along with all subsequent bytes that belong to it. When a bundle is fully received the DtnAgent issues a custody acceptance report targeted to the upstream node. At the reception of a custody acceptance the upstream node removes the corresponding bundle from storage. Partially received bundles are considered as placeholders and assumed to occupy the full bundle size, so that once a bundle is accepted there is guaranteed enough space for it to be fully received.

The DtnAgent implements a basic retransmission mechanism in order to ensure that custody for a bundle has been successfully transferred. In the TCP convergence layer case no action relative to the retransmission timer is taken the instant when a bundle is added to the TcpDtnAgent queue. Instead, the TcpDtnAgent notifies the DtnAgent through a callback function when the last part of a queued bundle has been actually transmitted and a retransmission timer is then started. In the UDP convergence layer case the timer is set as soon as the bundle is added to the link queue. The DtnAgent ensures that the retransmission timer is always set to the earlier retransmission time of the stored bundles. Reception of a custody rejection for a certain bundle resets its retransmission time, while reception of a custody acceptance updates the retransmission timer in case the relevant bundle was the earliest bundle pending for retransmission. In both cases, when TCP is employed, the downstream TcpDtnAgent is notified in order to remove data related to the reported bundle from its queue (so as to avoid redundant data transmission). When UDP is employed, the in-flight bundles are already in the link queue and, therefore, transmission cannot be aborted.

Currently, the retransmission timeout is set by the user to a constant value. However, sophisticated timeout calculation mechanisms can be easily fitted into the model. If the timeout value is set to 0, then no retransmissions occur whatsoever. Instead, a bundle is removed from storage as soon as it

either finishes transmitting or a custody rejection report arrives for it. Possible pending transmission for the removed bundle is canceled.

Additionally to the basic functionality described so far, the DTN model is equipped with a rendezvous (RV) mechanism, whose goal is to improve energy efficiency on mobile networking devices. The RV mechanism is employed at the last hop (wireless connection) of a data transfer originated from some wired node and targeted to a mobile device on a 802.11 WLAN. In such a scenario, minimal DTN deployment involves attaching DtnAgents at the source node, the Base Station (BS) and the destination (mobile node). Incoming data is buffered at the DtnAgent attached to the BS and flushed at certain RV times, allowing the receiver to switch its wireless interface to the sleep state in the meantime. At RV time the BS fragments bundles that have been partially received during the previous idle period and sends them on the wireless link. Meanwhile, bytes belonging to the original unfragmented bundle (which can be a fragment of another bundle itself) are still being received by the BS from the upstream node. The RV mechanism can only be employed along with TCP as the convergence layer.

Even though the RV mechanism is a feature designed to test a particular research proposition, the dynamic fragmentation of bundles (very similar to reactive fragmentation) can be useful in a variety of scenarios. For instance, DTN nodes can dynamically fragment bundles in a way that balances storage space occupation over the network. Fragment size can even be negotiated with the downstream node in cases storage space is very limited.

Connectivity Plan Routing Protocol (CARPOOL)

The majority of people living in the developed world are already experiencing how access to the Internet is transforming their way of living. Internet has now become a critical infrastructure for the society with its availability levels increasing and its traffic volume constantly growing. Based on this consensus, in 2011 the United Nations declared Internet access itself a human right. In a constantly evolving and expanding digital world, however, geographical isolation and socio-economic restrictions pose barriers to the invasion of the Internet to all parts of the society: remote regions demand significantly higher cost for Internet deployments, while economic challenges exclude the under-privileged from accessing the Internet even in well-connected environments.

Delay/Disruption Tolerant Networking (DTN) architecture and its supporting Bundle Protocol (BP) is an emerging technology to support the new era in interoperable communications by providing delay-tolerant access even when traditional continuous end-to-end connectivity fails. DTN has been frequently coupled with the concept of message ferrying, especially as far as remote areas are concerned, to facilitate data transfers through cars, buses, trams, trains etc.

SPICE researchers have focused on metropolitan environments with an ultimate goal to extend free delay-tolerant Internet access to the under-privileged society that is currently excluded from today's digital world. To achieve that, we extend the existing free Internet access provided by public hotspots that are usually scattered around a city. Actually, we broaden connectivity options by deploying DTN nodes both on typical means of public transport (ferries), such as buses and trams, and their corresponding stops. Offline DTN gateways located near ferry stops collect Internet access requests from end-users in that area and DTN ferries act as relays between offline gateways or designated gateways that have access to the Internet and are capable of handling such requests. In order to support the proposed access model, we have designed and implemented CARPOOL, a DTN routing protocol that utilises a priori knowledge of the connectivity plan to deliver bundles among DTN gateways. The CARPOOL protocol has been implemented and evaluated using the Opportunistic Network Environment (ONE) simulator.

Information Centric Delay Tolerant Networking: An Internet architecture for the challenged

Enabling universal Internet access is one of the key issues that is currently being addressed globally. However the existing Internet architecture is seriously “challenged” to ensure universal service provisioning. This short paper puts forth our vision to make the Internet more accessible by architecting a universal communication architectural framework combining two emerging architecture and connectivity approaches: Information Centric Networking (ICN) and Delay/Disruption Tolerant Networking (DTN). Such a unified architecture will aggressively seek to widen the connectivity options and provide flexible service models beyond what is currently pursued in the game around universal service provisioning.

We propose to address these challenges with the vision of making the Internet ubiquitous, accessible and energy- efficient. We do this by traversing a range of connectivity options that ensure universal coverage, while providing a single unifying communication architecture with a single set of abstractions that not only spurs innovation for a wide range of new services and applications but also encompasses existing successful Internet services. We utilise advances in information-centric networking (ICN) to provide this abstraction - an abstraction driven by access to and provisioning of information rather than the connection to explicitly identified endpoints.

Through this abstraction, we accommodate today’s web-based services while providing a path to future immersive and sensor-rich applications, such as those envisioned by the Internet of Things. The focus on information enables inherent support for rich caching policies that ultimately increase the efficiency of the network across different technologies by providing information from the most efficient provider rather than the original source.

The concept of overarching ICN enables us to pursue multiple complementary connectivity options, specifically including Delay Tolerant Networking (DTN), as distinct dissemination strategies, each of which constitutes a set of protocols that optimally utilise local resources. Integrating multiple concurrent dissemination strategies enables the utilisation of connected and disconnected modes of access under a single architectural (information-centric) abstraction. This enables us to accommodate a pure IP-based world as much as a challenged connectivity DTN world, all within a single architecture, while exploiting all possible communication opportunities that particular network deployments provide, ranging from fixed, all-optical deployments of wireless and mobile networks to satellite-supported deployments that cover difficult-to-reach environments.

Potential impact and the main dissemination activities and exploitation of results

The impact of SPICE project can be highlighted in the various dissemination and exploitation activities that have taken place throughout the duration of SPICE project.

Research publications

Through SPICE project, Space Internetworking Center has published its research work in top conferences and journals on the field. A detailed list of these publications is provided in the next section.

Presentations to other research institutes and universities

In order to achieve effective dissemination of the research results, several lectures and presentations of SPICE achievements to other research institutions were organised. These presentations attracted the interest of collaborating researchers in the field of space networking technologies and acted as initiators for future collaborations.

Standardisation activities

SPICE researchers actively participate in one standardisation organisation (the Consultative Committee for Space Data Systems) and one pre-standardisation research group (the Global Access to the Internet for All) IRTF research group.

CCSDS

Founded in 1982 by the major space agencies of the world, the CCSDS is a multi-national forum for the development of communications and data systems standards for spaceflight. Today, leading space communications experts from 26 nations collaborate in developing the most well engineered space communications and data handling standards in the world. The outmost goal is to enhance governmental and commercial interoperability and cross-support, while also reducing risk, development time and project costs. Till now, more than 500 space missions have chosen to fly with CCSDS-developed standards, and the number continues to grow.

CCSDS meetings take place twice per year, every spring and fall. Prof. Tsaoussidis, SPICE project coordinator, participates in the following CCSDS workgroups:

- Opening Plenary
- SEA System Architecture
- MOIMS Spacecraft Monitor and Control
- CSS Plenary
- CSS Service Management
- CSS Cross Support Transfer Services
- CSS Cross Support Architecture
- SLS Plenary
- SLS RFM/RNG
- SLS Space Link Coding and Synchronisation
- SLS Space Link Protocols
- SLS High Rate Uplink
- SIS Plenary
- SIS Asynchronous Messaging Service
- SIS IP over CCSDS
- SIS Mars Communication Profile
- SIS Voice BOF

- SIS Motion and Imagery Application BOF
- SIS DTN BOF
- Joint SIS-AMS and MOIMS-SMC
- Joint SIS-AMS and SOIS-ASS
- Joint CSS-SM and MOIMS-SMC

SPICE director, Prof. Vassilis Tsaoussidis, has been participating in the DTN-related groups of the CCSDS for the last six years, actively following the developments in the area of Space Internetworking.

GAIA

The Internet Society's recent global Internet survey reveals that the Internet should be considered as a basic human birth right like clean water, public roads, work/school etc., because of its societal benefits. However, in the reality of today's Internet, the vision of global access to the Internet faces the challenge of a growing digital divide, i.e., a growing disparity between those with sufficient access to the Internet and those who cannot afford access to the essential services provided by the Internet.

Access problems often result from sparsely spread populations living in physically remote locations, since it is simply not cost effective for Internet Service Providers (ISPs) to install the required infrastructure for broadband Internet access to these areas. In addition to the physical limitations of terrestrial infrastructures (mainly due to distance) to provide last mile access, remote communities also incur higher costs for connection between the exchange and backbone network when using wired technologies. A large exchange may accommodate many users and allow for competition between service operators; in contrast, a rural/remote broadband often does not offer economies of scale, raising the costs per user. Thus, although service requirements for customers in rural/remote areas and cities are identical, the delivery mechanism needs to be different.

Addressing digital exclusion due to socio-economic barriers is also extremely important. The United Nations revealed the global disparity in fixed broadband access, showing that access to fixed broadband mainly in less-developed countries costs almost 40 times their national average income. This problem is even encountered in developed countries, where many individuals find themselves unable to pass a necessary credit check or live in circumstances that are too unstable to commit to lengthy broadband contracts.

There are both policy and research challenges to the realisation of a future Internet capability that will offer appropriate access to all parts of society. There can be no single uniform solution that embraces all types of user and all locations.

The Global Access to the Internet for All (GAIA) is an IRTF initiative that aims:

- 1) to create maximum visibility and interest among the community on the challenges in enabling global Internet access;
- 2) to create a shared vision among researchers, corporations, non governmental and governmental organisations on the challenges;
- 3) to articulate and foster collaboration among them to address the diverse Internet access and architectural challenges;
- 4) to document and share deployment experiences and research results to the wider community through scholarly publications, white papers, Informational and Experimental RFCs etc;
- 5) to have a longer term vision on influencing standardisation efforts at the IETF that could potentially change the Internet landscape to be more inclusive.

SPICE staff member Ioannis Komnios actively participates in the GAIA research group and works on issues like providing low-cost Internet access to the underprivileged and achieving better exploitation of backhaul links in wireless community networks.

SPICE Website

The website of SPICE project and the Space Internetworking Center (www.spice-center.org) has been available since the beginning of SPICE project and has been constantly been updated with latest SPICE news, research achievements, scheduled events etc.

“SPICE Update” Newsletter

SPICE achievements have been regularly circulated to all interested parties through “SPICE Update” newsletter. “SPICE Update” is published three times per year, since the beginning of SPICE project. SPICE Update details the latest achievements of Space Internetworking Center, provides access to the latest publications, promotes SPICE dissemination activities and lists upcoming events. The newsletter has attracted the interest of the research community since the beginning and is even re-distributed by NASA’s DTN website. All issues of “SPICE Update” newsletter are publicly available online: <http://www.spice-center.org/newsletters/>

“SPICE Activity Summary” booklet

Towards the end of SPICE project, SPICE technical leader Ioannis Komnios produced a “SPICE Activity Summary” booklet that comprises an overview of the project (exchange of know-how, developed software, events etc.). “SPICE Activity Summary” is available on SPICE website (http://www.spice-center.org/files/final-event/booklet_final.pdf).

SPICE promotional video

SPICE researchers produced a promotional video for the Space Internetworking Center. The 15-minute video provides an insight in the Space Internetworking Center, its activities and the most promising software that was developed by SPICE researchers. The video was distributed to all participants of the final dissemination event of SPICE project and is publicly available on the homepage of SPICE website (www.spice-center.org).

Workshops and panel sessions

Throughout the duration of SPICE project, the Space Internetworking Center has organised at least one large dissemination event per year, including workshops and panel sessions. Below we detail the major events.

Panel session on Space Internetworking, Barcelona, Spain

Space Internetworking Center (SPICE) organised a session on Space Internetworking in parallel to the 9th International Conference on Wired/Wireless Internet Communications (WWIC) in Vilanova i la Geltru, Barcelona, Spain on June 16-17, 2011. The session consisted of two keynote presentations by invited speakers:

- Mr Scott Burleigh, senior researcher at Jet Propulsion Laboratory (NASA) and
- Mr Nestor Peccia, head of the Data Systems Infrastructure Division, Ground Engineering Department (ESA),

as well as one panel session between them.

The first keynote presentation by Mr Scott Burleigh took place on June 16th, 2011 and its main goal was to familiarise audience with the emerging technology of DTN in space and terrestrial communications. The presentation was entitled “Tortoise and Hare: Ways of thinking about mission communication” and focused on different communication technologies for Space.

The next part of the Space Internetworking session was the panel session between Mr Scott Burleigh (NASA) and Mr Nestor Peccia (ESA). Prof. Tsaoussidis was the moderator of the discussion. At the beginning, Prof. Tsaoussidis presented the two invited speakers and made a short introduction on space internetworking, in order to highlight why space internetworking is needed. In the main part of the panel discussion, Prof. Tsaoussidis asked five questions on space internetworking and speakers were called to answer in the form of a debate. In particular, Mr Burleigh and Mr Peccia discussed on:

- (Why) Is DTN an appropriate technology for Space?
- How can DTN become a technology of choice for space?
- What are the issues to solve until DTN becomes a Space technology
- What are the plans of each agency on Space Internetworking
- Open issues (including funding opportunities?)

Each participant was provided with enough time to express his ideas, as well as his agency's policies and strategy. At the end of the panel session, participants had the opportunity to ask questions to both speakers and discuss on DTN technology and the different space internetworking strategies of ESA and NASA. The moderator concluded the panel session with a short summary on the advantages of DTN technology. A total of 47 participants of the WWIC conference attended the panel session and the duration of the panel session was 2 hours.

On June 17th, 2011 the session on Space Internetworking was concluded with a keynote presentation from Mr Nestor Peccia entitled "ESA roadmap for a full DTN based Space Internetwork System". Since the audience had already been informed on DTN technology and the main space internetworking strategy of both ESA and NASA, the representative of ESA focused on ESA's plans to move from static to dynamic communication procedures.

Workshop on terrestrial and space DTN, Xanthi, Greece

Space Internetworking Center (SPICE) organised a workshop on "Terrestrial and Space DTN" in Xanthi, on September 6th, 2011. All speakers are recognised researchers in the field of DTN that have undertaken several research projects on the topic and developed several applications for Delay/Disruption Tolerant Networks. The workshop consisted of two parts; the first one was open to all interested parties, while the second one was restricted among researchers.

In the first part, five keynote presentations had been planned. In particular, presentations were given by:

- (1) Scott Burleigh, senior researcher at Jet Propulsion Laboratory, NASA, USA,
- (2) Jörg Ott, Professor at Aalto University, Finland,
- (3) Torsten Braun, Professor at University of Bern, Switzerland,
- (4) Eiko Yoneki, senior researcher at Cambridge University, United Kingdom, and
- (5) Lefteris Mamatras, senior researcher at SPICE, Greece.

The second part was a brainstorming session, where SPICE staff members discussed with other researchers on SPICE research agenda, in regards to upcoming FP7 calls.

The total duration of the workshop was 7 hours. Forty people attended the first part, while in the second part 15 researchers participated.

Delay- and Disruption- Tolerant Networks (DTN) workshop, Island of Santorini, Greece

During the second year of SPICE project, as part of the dissemination activities, SPICE organised a workshop on Delay- and Disruption- Tolerant Networks (DTNs). Considering the successful organisation of last year's panel discussion within the 9th International Conference on Wired/Wireless Internet Communications (WWIC 2011) and the high attendance of researchers

working in the area of DTN expected in this year's conference, it was decided for the DTN workshop to be integrated into the program of the 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012) as a two-day event. WWIC 2012 took place on the island of Santorini, Greece, between June 6th-8th, 2012, and the events of the workshop were scheduled for June 7th and 8th, 2012.

WWIC conference attracts high-quality research papers on modern Internet communication technologies and during the last years has shown a strong focus on DTN technology. Thus, the integration of the workshop within the conference constitutes a great opportunity for Space Internetworking Center to promote its achievements and the latest advances on DTN. The final program of the workshop on "Delay- and Disruption- Tolerant Networks (DTNs)" included:

- A keynote speech from Jörg Ott, a recognised researcher among the DTN research community;
- A panel discussion on "Delay- and Disruption-Tolerant Networks (DTNs): Challenges, Limitations and Application Scenarios";
- A general discussion on "Future of Delay- and Disruption-Tolerant Networks (DTNs) and Related Projects" and
- Two conference sessions specifically targeted on DTN research issues; the former includes invited papers on DTN, while the latter consists of peer reviewed research papers on Delay-Tolerant and Opportunistic Networks.

Workshop on DTN communications, Xanthi, Greece

During the third year of SPICE project, SPICE organised a workshop on Delay Tolerant Networking (DTN) communications. SPICE facilities in Xanthi, Greece, were preferred as a venue for the workshop, in order to better disseminate the achievements of the Space Internetworking Center to the local academic community, including undergraduate students, professors and researchers. The list of invited speakers for the workshop was formed based on the active collaborations between SPICE and other, mainly European, research institutes. The workshop was also an opportunity for SPICE researchers to meet with the collaborating researchers, discuss the ongoing work and plan joint future activities. The workshop was organised as a single-day event on June 18th, 2013, and was attended by 34 participants. Based on our previous experience from successfully organising similar events, we managed to bring together researchers from the region of Thrace and researchers from top universities and research institutes.

The workshop was held at the premises of SPICE, which are co-located with the Department of Electrical and Computer Engineering of the Democritus University of Thrace, in Xanthi, Greece. In particular, the workshop took place at the presentation room of the Space Internetworking Center, which has the capacity to accommodate 50 attendees. All speakers were recognised researchers in the field of DTN, or closely related research areas, that have undertaken several research projects on the topic.

The workshop was organised as a single-day event and consisted of three parts. At the beginning, Prof. Tsaoussidis, chair of the workshop, gave a short welcome talk, introduced the scope of the workshop and briefly presented the speakers. In the first part, five talks were given by highly recognised researchers in the area of DTN or closely related research areas. The second part of the workshop included a talk from Mr Grzegorz Ambroziewicz, EC's Policy officer and SPICE project officer, on FP7 Project Management and the new funding opportunities in the context of "Horizon 2020" EU's Framework Programme for Research and Innovation. In the third part, a discussion on the future of Delay- and Disruption- Tolerant Networking was held among workshop participants.

The event was open for participation to all interested parties. The detailed program of the workshop can be found at <http://www.spice-center.org/workshop-dtn-communications/>.

The list of invited speakers included:

- Dr Arjuna Sathiaseelan, senior researcher at the Computer Lab of University of Cambridge, UK;
- Scott Burleigh, senior researcher at the Jet Propulsion Laboratory of the National Aeronautics and Space Administration (NASA), USA;
- Dr Lefteris Mamatras, senior researcher at University College London, UK;
- Prof. Ioannis Stavrakakis, Professor at the Department of Informatics and Telecommunications of National and Kapodistrian University of Athens, Greece;
- Prof. Panagiotis Papadimitriou, Professor at the Leibniz University of Hannover, Germany and
- Grzegorz Ambroziewicz, EC's policy officer.

Each speaker was provided with 40 minutes time to present his achievements on the field and discuss with workshop participants.

Final large-scale dissemination event for SPICE project, Xanthi, Greece

The final large-scale dissemination event for SPICE project, along with the organization of a workshop on Space Internetworking, had been planned towards the end of SPICE project. Given the scale of the event, the Xenia Hall of Hotel Elisso in Xanthi, Greece, was selected as the most appropriate venue for the workshop in order to better accommodate the participants. The list of invited speakers for the workshop was formed based on the active collaborations between SPICE and other, mainly European, research institutes. The workshop was also an opportunity for SPICE researchers to meet with the collaborating researchers, discuss the ongoing work and plan joint future activities. The workshop was organized as a single-day event on June 10th, 2014, and was attended by 100 participants. Based on our previous experience from successfully organizing similar events, we managed to bring together researchers from the region of Thrace, researchers from top universities and research institutes, and representatives from local authorities.

The workshop was held at Hotel Elisso, which is located in the Old Town of Xanthi, Greece. In particular, the workshop took place at the Xenia Hall conference room of which has the capacity to accommodate 400 attendees for conferences and special events. All speakers were recognized researchers in the fields of space internetworking and DTN, or closely related research areas, that have undertaken several research projects on the topic, along with EU and local authorities representatives. The workshop was organized as a single-day event and consisted of three parts. At the beginning, Prof. Tsaoussidis, chair of the workshop, gave a short welcome talk, introduced the scope of the workshop and briefly presented the speakers. In the first part, SPICE team members gave ten brief talks on SPICE activities and research achievements.

The second part included three talks in the area of European and local actions regarding research potential, knowledge dissemination and investment planning. In particular, talks were given from:

- *Lucas Janssen*, European Commission Policy Officer;
- *Petros Soukoulis*, Director of the regional council of innovation and entrepreneurship in Eastern Macedonia and Thrace and
- *Prof. Spyridon Rapsomanikis*, Director of the laboratory of atmospheric pollution and pollution control engineering of Democritus University of Thrace.

In the third part, eight talks were given by highly recognised researchers in the areas of space internetworking and DTN, or closely related research areas, together with a discussion on the potential applications of DTN. In particular, talks were given from:

- *Kim Nergaard*, Head of Advanced Mission Concepts office, Mission Operations Department, European Space Agency – ESOC;
- *Gioacchino Buscemi*, ICT Network and Security Officer, European Space Research Institute, European Space Agency – ESRIN;
- *Scott Burleigh*, Principal Engineer, JPL/NASA, California Institute of Technology;
- *Sergey Gorinsky*, Research Associate Professor, IMDEA Networks;
- *Eiko Yoneki*, EPSRC Research Fellow, University of Cambridge, UK;
- *Prof. Torsten Braun*, Director of the Institute of Computer Science and Applied Mathematics, University of Bern;
- *Prof. Carlo Caini*, Professor of Telecommunications, University of Bologna and
- *Artemis Voyatzis*, Associate Researcher, ISI/RC “Athena”.

The event was open for participation to all interested parties. The duration of the workshop was approximately eight hours, including lunch and coffee breaks. Overall, the organisation of the workshop was successful, attracting the interest of professors and students of the Democritus University of Thrace, the local community and the local media.

Journal Special Issues

Special Issue on Future Internet Architecture

In the framework of SPICE project, Space Internetworking Center published a Special Issue on Future Internet Architectures in the Journal of Internet Engineering (JIE).

The Journal of Internet Engineering (JIE) aims at focused research on the architecture of next generation Internet, the future Internet protocol sets and their extensions, as well as the design properties of supportive middleware. The strategic and distinct aim of the journal places the Internet at the research core, targeting new engineering approaches, which will host naturally the evolutionary applications, as well as specific network architectures, protocols and devices.

The special issue on "Future Internet Architectures" includes articles on new protocols and mechanisms for the Future Internet. Strong emphasis is put on delay and disruption tolerant networking (DTN). Voyatzis gives an overview on DTN implementation platforms, experimentation networks as well as applications. Vardalis et al. investigate the potential of DTN to save energy, which is important since mobile end systems have limited battery power and lifetime. Rodríguez-Fernández present and discuss an approach to interconnect communities in rather heterogeneous networks, e.g., IP, mobile ad-hoc and DTN networks. Other challenging networks are satellite-networks. The article of Rendon-Morales presents an algorithm to parametric scheduling parameters to support Quality-of-Service in satellite networks. Finally, Dunaytsev et al., discuss traffic management approaches for Peer-to-Peer traffic, in particular to avoid excessive traffic between different network domains.

The Special Issue on Future Internet Architectures is available at JIE website: www.jie-online.org

Special Issue on New Research Challenges in Mobile, Opportunistic and Delay-Tolerant Networks

Internet is extending beyond its fixed network infrastructure boundaries by gradually incorporating a wide range of challenging networks and autonomous devices, serving non-traditional user communities, such as space missions, disaster areas, and economically challenged populations. These

hybrid network environments require supportive strategies to exploit even the slightest communication opportunity. Furthermore, the complexity of this task increases if we also consider device constraints, energy aspects and application diversity. In this context, what appears theoretically possible becomes conditionally feasible only when all available network resources are being efficiently exploited, including those hosted in nearby fixed deployments.

New research paradigms can give a unification perspective to the various pieces of the global network jigsaw puzzle. Software-Defined Networks (SDNs), Mobile Cloud Computing and Information-Centric Networks (ICNs) are among the recent innovations that can enable flexible solutions for integrating infrastructure with mobile and opportunistic networks, addressing challenging network conditions, and supporting promising new applications.

This Elsevier Ad Hoc Networks Special Issue aims at soliciting original manuscripts on experimental & theoretical work revisiting the research areas of mobile and opportunistic networks in the context of recent developments in networking research, including new fixed network technologies and concrete use-cases (e.g., disaster situations, space environments and free Internet deployments). On the one hand, infrastructure networks are becoming more flexible and can provide a supportive environment in which mobile-to-mobile communication can flourish, e.g., improving the Quality of Experience (QoE) and energy efficiency for users and devices, respectively. On the other hand, the deployed opportunistic networks can extend the pool of available resources and increase network coverage worldwide.

More information on this special issue can be found at:

<http://www.journals.elsevier.com/ad-hoc-networks/call-for-papers/special-issue-on-new-research-challenges-in-mobile/>

Strategy for the future of Space Internetworking Center

In order to guarantee sustainability with the end of SPICE project, SPICE developed a strategic plan whose purpose is to exploit the potential options of the Space Internetworking Center to move forward after the end of SPICE project. In particular, the plan explores research and funding opportunities, the legal framework of Greece in terms of different legal entities and their operational flexibility.

SPICE sustainability plan has been based on the strategic goals of SPICE, the relevant funding opportunities and the required funds to guarantee the operational autonomy of SPICE. The main criteria for the development of the sustainability plan are:

- What is the operational budget of SPICE per year?
- What is the external funding level that SPICE team can secure?
- Is there a stabilizing point between expenses and attracted funds?

Address of project public website and relevant contact details

The project public website can be found in the address:

www.spice-center.org

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4.2 Use and dissemination of foreground

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers ² (if available)	Is/Will open access ³ provided to this publication?
1	<i>Delay Tolerant Payload Conditioning protocol</i>	<i>Giorgos Papastergiou</i>	<i>Computer Networks</i>	<i>Vol. 59</i>	<i>Elsevier</i>	<i>Netherlands</i>	<i>2014</i>	<i>244-263</i>	http://dx.doi.org/10.1016/j.bjp.2013.11.003	No
2	<i>Delivery Time Estimation for Space Bundles</i>	<i>Nikolaos Bezirgiannidis</i>	<i>IEEE Transactions on Aerospace and Electronic Systems</i>	<i>Vol.49, No.3</i>	<i>Institute of Electrical and Electronics Engineers Inc.</i>	<i>United States</i>	<i>2013</i>	<i>1897-1910</i>	http://dx.doi.org/10.1109/TAES.2013.6558026	No
3	<i>Bundle streaming service: design, implementation and performance evaluation</i>	<i>Sotirios-Angelos Lenas</i>	<i>Transactions on Emerging Telecommunications Technologies</i>	<i>2013</i>	<i>Wiley</i>	<i>United Kingdom</i>	<i>2013</i>	<i>N/A</i>	http://dx.doi.org/10.1002/ett.2762	No
4	<i>Exploiting the potential of DTN for energy-efficient internetworking</i>	<i>Dimitris Vardalis</i>	<i>Journal of Systems and Software</i>	<i>Vol. 90</i>	<i>Elsevier Inc.</i>	<i>United States</i>	<i>2014</i>	<i>91-103</i>	http://dx.doi.org/10.1016/j.jss.2013.12.035	No
5	<i>Privacy-preserving computation of participatory noise maps in the cloud</i>	<i>George Drosatos</i>	<i>Journal of Systems and Software</i>	<i>Vol. 92</i>	<i>Elsevier Inc.</i>	<i>United States</i>	<i>2014</i>	<i>170-183</i>	http://dx.doi.org/10.1016/j.jss.2014.01.035	No
6	<i>Enabling free</i>	<i>Sotirios-Angelos</i>	<i>Mobile Computing</i>	<i>Vol.</i>	<i>ACM SIGMOBILE</i>	<i>United States</i>	<i>2014</i>	<i>55-63</i>	http://dx.doi.org	No

	<i>internet access at the edges of broadband connections</i>	<i>Lenas</i>	<i>and Communications Review</i>	<i>18/Issue 1</i>					<i>g/10.1145/2581555.2581564</i>	
7	<i>SPICE Testbed: A DTN Testbed for Satellite and Space Communications</i>	<i>Ioannis Komnios</i>	<i>9th International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TRIDENTCOM 2014), Guangzhou, China</i>	<i>07/05/2014</i>	<i>European Alliance for Innovation</i>	<i>N/A</i>	<i>2014</i>	<i>N/A</i>	<i>N/A</i>	<i>No</i>
8	<i>LEDBAT performance in sub-packet regimes</i>	<i>Ioannis Komnios</i>	<i>2014 11th Annual Conference on Wireless On-demand Network Systems and Services (WONS)</i>	<i>04/04/2014</i>	<i>IEEE</i>	<i>United States</i>	<i>2014</i>	<i>154-161</i>	<i>http://dx.doi.org/http://dx.doi.org/10.1109/WONS.2014.6814738</i>	<i>No</i>
9	<i>Towards Flexibility and Accuracy in Space DTN Communications</i>	<i>Nikolaos Bezirgiannidis</i>	<i>19th ACM International Conference on Mobile Computing and Networking</i>	<i>04/10/2013</i>	<i>ACM Press</i>	<i>United States</i>	<i>2013</i>	<i>43-48</i>	<i>http://dx.doi.org/10.1145/2505494.2505499</i>	<i>No</i>
10	<i>A Privacy-Preserving Cloud Computing System for Creating Participatory Noise Maps</i>	<i>George Drosatos</i>	<i>36th Annual IEEE Computer Software and Applications Conference</i>	<i>20/07/2012</i>	<i>IEEE</i>	<i>United States</i>	<i>2012</i>	<i>581-586</i>	<i>http://dx.doi.org/10.1109/CO MPSAC.2012.78</i>	<i>No</i>
11	<i>CARPOOL: Extending Free Internet Access over DTN in Urban Environments</i>	<i>Ioannis Komnios</i>	<i>19th ACM International Conference on Mobile Computing and Networking</i>	<i>04/10/2013</i>	<i>ACM Press</i>	<i>United States</i>	<i>2013</i>	<i>21-23</i>	<i>http://dx.doi.org/10.1145/2502880.2502891</i>	<i>No</i>

12	<i>Traffic Shaping for Enabling Less-than-Best Effort Services at the Edges of Broadband Connections</i>	Sotirios-Angelos Lenas	19th ACM International Conference on Mobile Computing and Networking	04/10/2013	ACM Press	United States	2013	41-46	http://dx.doi.org/10.1145/2502880.2502888	No
13	<i>Requirements for a Forensically Ready Cloud Storage Service</i>	Theodoros Spyridopoulos	International Journal of Digital Crime and Forensics	Volume 3, Issue 3	IGI Global Publishing	United States	2011	19-36	http://dx.doi.org/10.4018/jdcf.2011070102	No
14	<i>Energy-efficient internetworking with DTN</i>	Dimitris Vardalis	Journal of Internet Engineering, Special Issue on Future Internet Architectures	Vol 5, No 1	Kleidarithmos Press	Greece	2012	345-354	N/A	Yes
15	<i>Exploiting Communication Opportunities in Disrupted Network Environments</i>	Lefteris Mamatas	Journal of Internet Engineering	Vol. 6, No. 1	Klidarithmos Press	Greece	2014	N/A	N/A	Yes
16	<i>A Survey of P2P Traffic Management Approaches: Best Practices and Future Directions</i>	Roman Dunaytsev	Journal of Internet Engineering, Special Issue on Future Internet Architectures	Vol 5, No 1	Kleidarithmos Press	Greece	2012	318-330	N/A	Yes
17	<i>A Heaviest Hitters Limiting Mechanism with O(1) Time Complexity for Sliding-Window Data Streams</i>	Remous-Aris Koutsiamanis	Journal of Internet Technology	Vol. 14 No. 1	Taiwan Academic Network Management Committee	Taiwan	2013	117-126	N/A	No
18	<i>Predicting Queueing Delays in Delay Tolerant Networks with Application in Space</i>	Nikolaos Bezirgiannidis	12th International Conference on Wired & Wireless Internet Communications (WWIC 2014), Paris, France	28/05/2014	Springer Berlin Heidelberg	Germany	2014	N/A	N/A	No

19	CARPOOL: Connectivity Plan Routing Protocol	Ioannis Konnios	12th International Conference on Wired & Wireless Internet Communications (WWIC 2014), Paris, France	28/05/2014	Springer Berlin Heidelberg	Germany	2014	N/A	N/A	No
20	Packet size and DTN transport service: Evaluation on a DTN testbed	Nikolaos Bezergiannidis	2nd International Congress on Ultra Modern Telecommunications and Control Systems	20/10/2010	IEEE	United States	2010	1198 - 1205	http://dx.doi.org/10.1109/ICU-MT.2010.5676669	No
21	Where does transport layer fit into Space DTN architecture?	Giorgos Papastergiou	5th Advance Satellite Multimedia Systems Conference	15/09/2010	IEEE	United States	2010	81-88	http://dx.doi.org/10.1109/AS-MS-SPSC.2010.5586851	No
22	Reliable Data Streaming over Delay Tolerant Networks	Sotirios-Angelos Lenas	10th International Wired/Wireless Internet Communications Conference	08/06/2012	Springer	Germany	2012	358-365	http://dx.doi.org/10.1007/978-3-642-30630-3_33	No
23	Routing for Opportunistic Networks Based on Probabilistic Erasure Coding	Fani Tsapeli	10th International Wired/Wireless Internet Communications Conference	08/06/2012	Springer	Germany	2012	257-268	http://dx.doi.org/10.1007/978-3-642-30630-3_22	No
24	Achieving energy- efficiency with DTN: A Proof-of-concept and roadmap study	Dimitris Vardalis	10th International Wired/Wireless Internet Communications Conference	08/06/2012	Springer	Germany	2012	332-341	http://dx.doi.org/10.1007/978-3-642-30630-3_30	No
25	On the Performance of Erasure Coding over Space DTNs	Giorgos Papastergiou	10th International Wired/Wireless Internet Communications Conference	08/06/2012	Springer	Germany	2012	269-281	http://dx.doi.org/10.1007/978-3-642-30630-3_23	No

26	<i>Towards a low-cost, full-service air quality data archival system</i>	Argyris Samourkasidis	<i>7th International Congress on Environmental Modelling and Software San Diego, California, USA</i>	19/06/2014	Creative Commons License	-	2014	N/A	N/A	Yes
27	<i>Enhancing Deniability against Query-Logs</i>	Avi Arampatzis	<i>33rd European Conference on Information Retrieval</i>	21/04/2011	Springer	Germany	2011	117-128	http://dx.doi.org/10.1007/978-3-642-20161-5_13	No
28	<i>Towards a forensically ready cloud storage service</i>	Theodoros Spyridopoulos	<i>6th International Annual Workshop on Digital Forensics and Incident Analysis</i>	08/07/2011	Kingston University, London, UK	UK	2011	93-107	N/A	No
29	<i>Cirrus: A Disruption-Tolerant Cloud</i>	Eli Katsiri	<i>10th International Wired/Wireless Internet Communications Conference</i>	08/06/2012	Springer	Germany	2012	350-357	http://dx.doi.org/10.1007/978-3-642-30630-3_32	No
30	<i>A Versatile Tool for Privacy-Enhanced Web Search</i>	Avi Arampatzis	<i>35th European Conference on Information Retrieval</i>	27/03/2013	Springer	Germany	2013	368-379	http://dx.doi.org/10.1007/978-3-642-36973-5_31	No
31	<i>Money-Based Coordination of Network Packets</i>	Pavlos S. Efraimidis	<i>8th International Conference, CIAC 2013, Barcelona, Spain</i>	24/05/2013	Springer Berlin Heidelberg	Germany	2013	197-208	http://dx.doi.org/10.1007/978-3-642-38233-8_17	No
32	<i>Storage-Enabled Access Points for Improved Mobile Performance: An Evaluation Study</i>	Efthymios Koutsogiannis	<i>9th International Wired/Wireless Internet Communications Conference</i>	17/06/2011	Springer	Germany	2011	116-127	http://dx.doi.org/10.1007/978-3-642-21560-5_10	No
33	<i>Queue-Management Architecture for Delay Tolerant</i>	Sotirios-Angelos Lenas	<i>9th International Wired/Wireless Internet Communications</i>	17/06/2011	Springer	Germany	2011	470-482	http://dx.doi.org/10.1007/978-3-642-21560-5_39	No

	<i>Networking</i>		<i>Conference</i>							
34	<i>A heaviest hitters limiting mechanism with $O(1)$ time complexity for sliding-window data streams</i>	<i>Remous-Aris Koutsiamanis</i>	<i>2nd FTRA World Convergence Conference</i>	<i>15/12/2011</i>	<i>Taiwan Academic Network Executive Committee</i>	<i>Taiwan</i>	<i>2011</i>	<i>N/A</i>	<i>N/A</i>	<i>No</i>

LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities ⁶	Main leader	Title	Date/ Period	Place	Type of audience ⁷	Size of audience	Countries addressed
1	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking and DTN	14/09/2010	2nd COST WINEMO meeting, Barcelona, Spain	Scientific community (higher education, Research) - Industry	33	20 European countries
2	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Where Does Transport Layer Fit into Space DTN Architecture?	15/09/2010	5th Advance Satellite Multimedia Systems Conference, Cagliari, Italy	Scientific community (higher education, Research)	20	Worldwide
3	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Packet size and DTN transport service: Evaluation on a DTN Testbed	19/10/2010	International Congress on Ultra Modern Telecommunications and Control Systems 2010, Moscow, Russia	Scientific community (higher education, Research)	25	Worldwide
4	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	27/10/2010	CCSDS Fall 2010 Meeting, London, United Kingdom	Scientific community (higher education, Research) - Industry - Policy makers	40	Worldwide
5	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	28/10/2010	Computer Laboratory, Cambridge University, London, United Kingdom	Scientific community (higher education, Research)	30	United Kingdom
6	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Internetworking Technologies for Space Science	04/04/2011	MIT, USA	Scientific community (higher education, Research)	30	USA
7	Presentations	DEMOCRITUS UNIVERSITY	Internetworking Technologies for Space Science	07/04/2011	Systems Engineering Division, NASA, USA	Industry	25	USA

⁶ A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

⁷ A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

		OF THRACE						
8	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Enhancing Deniability against Query-Logs	19/04/2011	The 33rd European Conference on Information Retrieval, Dublin, Ireland	Scientific community (higher education, Research)	20	Worldwide
9	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Storage-Enabled Access Points for Improved Mobile Performance: An Evaluation Study	15/06/2011	9th International Conference on Wired/Wireless Internet Communications, Barcelona, Spain	Scientific community (higher education, Research)	30	Worldwide
10	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Queue-Management Architecture for Delay Tolerant Networking	17/06/2011	9th International Conference on Wired/Wireless Internet Communications, Barcelona, Spain	Scientific community (higher education, Research)	20	Worldwide
11	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Towards a forensically ready cloud storage service	07/07/2011	6th International Annual Workshop on Digital Forensics and Incident Analysis (WDFIA 2011), London, UK	Scientific community (higher education, Research)	25	Worldwide
12	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Internetworking technologies for space science	15/09/2011	AALTO University, COMNET group, Helsinki, Finland	Scientific community (higher education, Research)	30	Finland
13	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Internetworking technologies for space science	19/09/2011	Tampere University, Department of Communication Engineering, Tampere, Finland	Scientific community (higher education, Research)	25	Finland
14	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A heaviest hitters limiting mechanism with O(1) time complexity for sliding-window data streams	12/12/2011	2011 FTRA World Convergence Conference	Scientific community (higher education, Research)	30	Worldwide
15	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Internetworking with DTN	10/05/2012	National and Kapodistrian University of Athens	Scientific community (higher education, Research)	15	Greece
16	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Achieving energy-efficiency with DTN: A Proof-of-concept and roadmap study	08/06/2012	Delay- and Disruption- Tolerant Networks (DTNs) workshop	Scientific community (higher education, Research)	40	Worldwide
17	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Cirrus: A Disruption-Tolerant Cloud	08/06/2012	Delay- and Disruption- Tolerant Networks (DTNs) workshop	Scientific community (higher education, Research)	40	Worldwide
18	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Reliable Data Streaming over Delay Tolerant Networks	08/06/2012	Delay- and Disruption- Tolerant Networks (DTNs) workshop	Scientific community (higher education, Research)	40	Worldwide

19	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Routing for Opportunistic Networks Based on Probabilistic Erasure Coding	08/06/2012	10th International Conference on Wired/Wireless Internet Communications, Santorini, Greece	Scientific community (higher education, Research)	40	Worldwide
20	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	On the Performance of Erasure Coding over Space DTNs	08/06/2012	10th International Conference on Wired/Wireless Internet Communications, Santorini, Greece	Scientific community (higher education, Research)	40	Worldwide
21	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center: Research activities and projects	18/04/2011	NATO's Underwater Research Center (NURC)	Scientific community (higher education, Research)	5	Italy
22	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Congestion control in next generation networking	27-28/04/2011	University of Sienna	Scientific community (higher education, Research)	30	Italy
23	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	SPICE research activities	16-20/05/2011	CCSDS Spring 2011 meeting	Scientific community (higher education, Research)	40	Worldwide
24	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	03/05/2012	Institute for the Management of Information Systems	Scientific community (higher education, Research)	15	Greece
25	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	04/05/2012	ATHENA Research Center	Scientific community (higher education, Research)	1	Greece
26	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A privacy-preserving cloud computing system for creating participatory noise maps	18/06/2012	IEEE COMPSAC 2012 Trustworthy Software Systems for the Digital Society	Scientific community (higher education, Research)	40	Worldwide
27	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTNator	29/09/2012	Hellenic Aerospace Industry	Industry	7	Greece
28	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Internetworking with DTN	05/10/2012	16th PanHellenic Conference on Informatics with International Participation (PCI 2012)	Scientific community (higher education, Research)	50	Worldwide
29	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A versatile tool for Privacy-Enhanced Web Search	27/03/2013	35th European Conference on Information Retrieval (ECIR 2013)	Scientific community (higher education, Research)	60	Worldwide
30	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Results	04/04/2013	University of Cambridge	Scientific community (higher education, Research)	8	UK

31	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	11/04/2013	Space Internetworks	Industry	7	Greece
32	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	SPICE: Internetworking with DTN	19/04/2013	University of Birmingham	Scientific community (higher education, Research)	12	UK
33	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Money-based coordination of network packets	22/05/2013	8 th International Conference on Algorithms and Complexity	Scientific community (higher education, Research)	60	Worldwide
34	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	09/06/2013	National and Kapodistrian University of Athens	Scientific community (higher education, Research)	30	Greece
35	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	28/08/2013	RAYCAP	Industry	2	Greece
36	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	DTN: Research and deployment perspectives	29/08/2013	General Secretariat of Research and Technology	Policy makers	1	Greece
37	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	CARPOOL: Extending free Internet access over DTN in urban environments	30/09/2013	ACM MobiCom Workshop on Lowest Cost Denominator Networking for Universal Access (LCDNet 2013)	Scientific community (higher education, Research)	12	Worldwide
38	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Traffic shaping for enabling less-than-best-effort services at the edges of broadband connections	30/09/2013	ACM MobiCom Workshop on Lowest Cost Denominator Networking for Universal Access (LCDNet 2013)	Scientific community (higher education, Research)	12	Worldwide
39	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Towards flexibility and accuracy in Space DTN communications	30/09/2013	8 th ACM MobiCom Workshop on Challenged Network (CHANTS 2013)	Scientific community (higher education, Research)	23	Worldwide
40	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Application of a BitTorrent-like data distribution model to mission operations	24-25/10/2013	European Space Agency (ESA/ESOC)	Scientific community (higher education, Research) Policy makers	12	Worldwide
41	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A new brain for the Internet	12/12/2013	3 rd IEEE International Symposium on Signal Processing and Information Technology (IEEE ISSPIT 2013)	Scientific community (higher education, Research)	80	Worldwide

42	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center: Projects and Research Interests	16- 17/12/2013	University of Bologna	Scientific community (higher education, Research)	30	Italy
43	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	LEDBAT Performance in Sub- packet Regimes	04/04/2014	11th IEEE/IFIP Annual Conference on Wireless On-demand Network Systems (IEEE/IFIP WONS 2014)	Scientific community (higher education, Research)	50	Worldwide
44	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Application of a BitTorrent-like data distribution model to mission operations: SPICE Results	29/04/2014	European Space Agency (ESA/ESOC)	Scientific community (higher education, Research) Policy Makers	12	Worldwide
45	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Space –data Routers: An overview	30/04/2014	European Geosciences Union General Assembly 2014	Scientific community (higher education, Research) Policy Makers	15	Worldwide
46	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A new brain for the Internet	05/05/2014	The Chinese University of Hong Kong (CUHK)	Scientific community (higher education, Research) Policy Makers	15	People's Republic of China
47	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A new brain for the Internet	09/05/2014	Hong Kong University of Science and Technology (HKUST)	Scientific community (higher education, Research) Policy Makers	5	People's Republic of China
48	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Testbed: A DTN Testbed for Satellite and Space Communications	06/05/2014	9th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities (TRIDENTCOM 2014)	Scientific community (higher education, Research) Policy Makers	45	Worldwide
49	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Predicting queuing delays in Delay Tolerant Networks with Application in Space	28/05/2014	12th International Conference on Wired and Wireless Internet Communications (WWIC 2014)	Scientific community (higher education, Research) Policy Makers	50	Worldwide
50	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	CARPOOL: Connectivity Plan Routing Protocol	28/05/2014	12th International Conference on Wired and Wireless Internet Communications (WWIC 2014)	Scientific community (higher education, Research) Policy Makers	50	Worldwide
51	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	A low-cost, full-service air quality data archival system	17/06/2014	7 th International Congress on Environmental Modelling and Software	Scientific community (higher education, Research) Policy Makers	400	Worldwide
52	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Official presentation of Space Internetworking Center"	20/09/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece

53	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Modeling Score Distributions in Information Retrieval & Applications"	05/10/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
54	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Algorithmic Game Theory"	11/10/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
55	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"The bodyguard"	18/10/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
56	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Cocktail party problem and proposed solutions"	25/10/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
57	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"www.MMRetrieval.net: A Multimodal Search Engine"	01/11/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
58	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Adaptive and optimization tools for Large-scale actuator/sensor networks"	23/11/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
59	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Current Advances in 3D Object Retrieval"	29/11/2010	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
60	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Short presentation of research work of SPICE researchers"	21/01/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
61	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Artificial vision: applications in robotic systems"	21/02/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
62	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Presentation of work on Software Technologies and Computation Systems Security"	28/02/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
63	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Ecoinformatics: Software engineering challenges for the environment's sake"	14/03/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
64	Presentations	DEMOCRITUS UNIVERSITY	"Computational tools for describing and designing"	21/03/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece

		OF THRACE	complex systems"					
65	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"An Open Source Set of Libraries to Control a 5-DOF Robotic Arm"	04/04/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
66	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	Colloquium: "Wired and Wireless Methods for Controlling a 5-DOF Robotic Arm"	04/04/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
67	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Infrastructure-Assisted Geo-Routing for Cooperative Vehicular Networks"	16/05/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
68	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Electronic Governance and Local Administration"	23/05/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
69	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Managing P2P Traffic: State-of-the-Art and Future Directions"	31/10/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
70	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Routing for Opportunistic Networks Based on Probabilistic Erasure Coding"	07/11/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
71	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Usage assessment of Internet applications"	21/11/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
72	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"User Mobility in Urban Areas as a semi Markov process"	23/11/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
73	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Electrodynamic simulations in the near-earth environment"	12/12/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
74	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Experience-Driven Procedural Content Generation"	19/12/2011	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
75	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Detection of Learner's Affective State Based on Mouse Movements"	16/01/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
76	Presentations	DEMOCRITUS	"Authenticated Key Exchange	06/02/2012	Space Internetworking Center	Scientific community (higher	30	Greece

		UNIVERSITY OF THRACE	(AKE) in Delay Tolerant Networks"			education, Research)		
77	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Study and Evaluation of HTTP load balancing techniques on the Internet"	12/03/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
78	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Satellite Toolkit (STK): Software to model, analyze and visualize space, defense and intelligence systems"	30/04/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
79	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Utility Based Routing"	09/05/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
80	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Graph Representation of Deterministic Delay Tolerant Networks"	17/05/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
81	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Erasure Coding in Space Communications"	25/05/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
82	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"PacketEconomy: a mechanism for best effort user-controlled QoS"	30/05/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
83	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Delay-Tolerant Communication with Content-Centric Networks"	13/06/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
84	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Admission to an organization and structure of a successful self-presentation"	09/11/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
85	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"New technologies in energy and transport"	07/12/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
86	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Separating transport from other services provided by Delay-Tolerant Payload Conditioning"	17/12/2012	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
87	Presentations	DEMOCRITUS UNIVERSITY	"DTN Queue Management"	14/01/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece

		OF THRACE						
88	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Bundle Delivery Time Estimation: a tool for predicting arrival time of space bundles"	28/01/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
89	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Message Ferry Routing in Delay Tolerant Networks"	11/02/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
90	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Multi-objective Contact Graph Routing Mechanism"	25/02/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
91	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Setting up a DTN testbed"	11/03/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
92	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Bundle Streaming Service"	26/03/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
93	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Mobile ICN-DTN-Assisted services using satellites for safety and security (MIDAS ³)"	10/04/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
94	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Towards a new ESA mission: Tuning the communication protocols"	16/04/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
95	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Offload 3G networks traffic through Delay Tolerant Networks"	25/04/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
96	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"A Study of Queueing Delay in Delay Tolerant Networks with Application in Space"	06/06/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
97	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Multicasting on Delay Tolerant Networks: The IMC-BSS Approach"	17/07/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
98	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Simulations of space missions"	17/09/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
99	Presentations	DEMOCRITUS UNIVERSITY	"Deploying the "Space-Data Routers" architecture to	10/10/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece

		OF THRACE	emulate realistic scenarios"					
100	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Interconnecting Heterogeneous Devices in Ad-Hoc Networks with Mobile Users"	18/10/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
101	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Interoperability testing and network performance evaluation of the major DTN implementations"	18/10/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
102	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"CARPOOL: Extending Free Internet Access over DTN in Urban Environments"	12/11/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
103	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Traffic shaping for enabling less-than-best effort services at the edges of broadband connections"	19/11/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
104	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"DUTH at TREC 2013 Contextual Suggestion Track"	10/12/2013	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
105	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"SPICE Testbed: A DTN Testbed for Satellite and Space Communications"	10/01/2014	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
106	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Predicting Queueing Delays in Delay Tolerant Networks with Application in Space"	28/01/2014	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
107	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"A DTN-based architecture for the dissemination of high volumes of space-data"	11/02/2014	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
108	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"Performance evaluation of routing algorithms in ad-hoc networks based on connectivity maps"	21/02/2014	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
109	Presentations	DEMOCRITUS UNIVERSITY OF THRACE	"DTN Sensor Data Carrier - Problem Description and Requirements Phase"	11/03/2014	Space Internetworking Center	Scientific community (higher education, Research)	30	Greece
110	Presentations	DEMOCRITUS	"LEDBAT performance in sub-	09/04/2014	Space Internetworking Center	Scientific community (higher	30	Greece

		UNIVERSITY OF THRACE	<i>packet regimes"</i>			<i>education, Research)</i>		
111	<i>Presentations</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>"ALPINE sensor network programming abstractions and tools"</i>	13/05/2014	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research)</i>	30	<i>Greece</i>
112	<i>Presentations</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>"Design, implementation and functional extensions to the Delay Tolerant Payload Conditioning (DTPC) protocol"</i>	29/05/2014	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research)</i>	30	<i>Greece</i>
113	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>SPICE Project Activity Summary</i>	10/06/2014	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	N/A	<i>Worldwide</i>
114	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>Information centric delay tolerant networking: An Internet Architecture for the challenged</i>	30/09/2013	<i>University of Cambridge</i>	<i>Scientific community (higher education, Research)</i>	N/A	<i>Worldwide</i>
115	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>Delivery Time Estimation for Space Bundles</i>	30/09/2012	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research)</i>	N/A	<i>Worldwide</i>
116	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>Energy-efficient internetworking with DTN</i>	30/10/2011	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research)</i>	N/A	<i>Worldwide</i>
117	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>SPICE Update Newsletter Volume 1 Issue 1</i>	31/10/2010	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	100	<i>Worldwide</i>
118	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>SPICE Update Newsletter Volume 2 Issue 1</i>	31/03/2011	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	150	<i>Worldwide</i>
119	<i>Publication</i>	DEMOCRITUS UNIVERSITY OF THRACE	<i>SPICE Update Newsletter Volume 2 Issue 2</i>	01/09/2011	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	150	<i>Worldwide</i>
120	<i>Publication</i>	DEMOCRITUS	<i>SPICE Update Newsletter</i>	20/12/2011	<i>Space Internetworking Center</i>	<i>Scientific community (higher</i>	150	<i>Worldwide</i>

		UNIVERSITY OF THRACE	Volume 2 Issue 3			education, Research) - Industry - Civil society - Policy makers - Medias		
121	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 3 Issue 1	31/05/2012	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	150	Worldwide
122	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 3 Issue 2	30/09/2012	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	200	Worldwide
123	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 3 Issue 3	15/12/2012	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	200	Worldwide
124	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 4 Issue 1	10/05/2013	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	200	Worldwide
125	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 4 Issue 2	30/09/2013	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	250	Worldwide
126	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 4 Issue 3	15/12/2013	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	300	Worldwide
127	Publication	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Update Newsletter Volume 5 Issue 1	30/04/2014	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	350	Worldwide
128	Publication	DEMOCRITUS UNIVERSITY OF THRACE	Transport protocols for delay-tolerant networks (PhD Thesis)	03/12/2010	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
129	Publication	DEMOCRITUS UNIVERSITY	Reliable transport protocols for delay-tolerant networks:	19/11/2012	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide

		OF THRACE	<i>Design and performance evaluation (PhD Thesis)</i>					
130	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Utilization and protection of personal data in ubiquitous computing environments (PhD Thesis)</i>	10/07/2013	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
131	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Protocol architecture for delay-tolerant networks (MSc Thesis)</i>	16/01/2011	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
132	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Providing QoS through scheduling (MSc Thesis)</i>	29/11/2010	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
133	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Design and performance evaluation of the basic functions of a space transport protocol that supports recording over delay-tolerant networks (MSc Thesis)</i>	21/12/2011	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
134	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Routing in opportunistic networks (MSc Thesis)</i>	31/01/2012	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
135	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Design, implementation and functional extensions to the Delay Tolerant Payload Conditioning (DTPC) protocol (MSc Thesis)</i>	29/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
136	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Bandwidth and Delay estimation in space networks (MSc Thesis)</i>	29/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
137	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Data security management through network management protocols (MSc Thesis)</i>	29/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
138	Publication	DEMOCRITUS UNIVERSITY OF THRACE	<i>Data retrieval for forensic analysis in computational clouds (MSc Thesis)</i>	10/02/2012	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
139	Publication	DEMOCRITUS	<i>Routing algorithms in high-load</i>	30/05/2012	Space Internetworking Center	Scientific community (higher	N/A	Greece

		UNIVERSITY OF THRACE	networks that aim at load balancing (Diploma Thesis)			education, Research)		
140	Publication	DEMOCRITUS UNIVERSITY OF THRACE	Implementation of a delay-tolerant network (Diploma Thesis)	18/10/2013	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
141	Publication	DEMOCRITUS UNIVERSITY OF THRACE	Interconnecting heterogeneous devices in ad hoc networks with moving objects (Diploma Thesis)	18/10/2013	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
142	Publication	DEMOCRITUS UNIVERSITY OF THRACE	Performance evaluation of routing algorithms in ad-hoc networks based on connectivity maps (Diploma Thesis)	21/02/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
143	Publication	DEMOCRITUS UNIVERSITY OF THRACE	Routing in vehicular ad hoc networks (Diploma Thesis)	30/06/2012	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Greece
144	Web sites/Applications	DEMOCRITUS UNIVERSITY OF THRACE	SPICE website	20/10/2010	www.spice-center.org	Scientific community (higher education, Research) - Industry - Civil society - Medias	10000	Worldwide
145	Web sites/Applications	DEMOCRITUS UNIVERSITY OF THRACE	Bundle Streaming Service (BSS)	14/04/2012	ION v3.0 software distribution	Scientific community (higher education, Research)	1000	Worldwide
146	Web sites/Applications	DEMOCRITUS UNIVERSITY OF THRACE	Delay Tolerant Payload Conditioning Protocol (DTPC)	30/05/2013	ION v3.0 software distribution	Scientific community (higher education, Research)	1000	Worldwide
147	Web sites/Applications	DEMOCRITUS UNIVERSITY OF THRACE	Bundle Delivery Time Estimation tool (BDTE)	30/03/2014	ION v3.0 software distribution	Scientific community (higher education, Research)	1000	Worldwide
148	Web sites/Applications	DEMOCRITUS UNIVERSITY OF THRACE	NS2 DTN Agent	01/06/2013	Network Simulator 2	Scientific community (higher education, Research)	1000	Worldwide
149	Organisation of Workshops	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on terrestrial and space DTN	06/09/2011	Elisso Hotel, Xanthi, Greece	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	35	Greece

150	Organisation of Workshops	DEMOCRITUS UNIVERSITY OF THRACE	Delay- and Disruption- Tolerant Networks (DTNs) workshop	07/06/2012	Santorini, Greece	Scientific community (higher education, Research)	50	Worldwide
151	Organisation of Workshops	DEMOCRITUS UNIVERSITY OF THRACE	Delay- and Disruption- Tolerant Networks (DTNs) workshop	08/06/2012	Santorini, Greece	Scientific community (higher education, Research)	50	Worldwide
152	Organisation of Workshops	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on DTN communications	18/06/2013	Space Internetworking Center	Scientific community (higher education, Research)	40	Greece
153	Organisation of Workshops	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking - SPICE Project final dissemination event	10/06/2014	Elisso Hotel, Xanthi, Greece	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	100	Greece
154	Videos	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center promotional video	06/06/2014	YouTube and SPICE website (https://www.youtube.com/watch?v=mZyP6E3-INQ)	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	N/A	Worldwide
155	Articles published in the popular press	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	12/10/2010	Naftemporiki newspaper	Civil society	3000	Greece
156	Articles published in the popular press	DEMOCRITUS UNIVERSITY OF THRACE	Plans for Internetworking technologies in Space	13/10/2010	Imerisia newspaper (http://www.imerisia.gr/article.asp?catid=12304&subid=2&pubid=68793147)	Civil society	200	Greece
157	Articles published in the popular press	DEMOCRITUS UNIVERSITY OF THRACE	Future plans for internetworking technology in Space	13/10/2010	Imerisia newspaper	Civil society	4000	Greece
158	Articles published in the popular press	DEMOCRITUS UNIVERSITY OF THRACE	Cities that... connect Greece!	19/10/2010	Eleftheros typos newspaper	Civil society - Medias	7000	Greece
159	Articles published in the popular press	DEMOCRITUS UNIVERSITY OF THRACE	Space Internet from Thrace	12/03/2011	Kathimerini newspaper (http://news.kathimerini.gr/4dcgi/_w_articles_economy_2_12/03/2011_435553)	Civil society - Medias	9000	Greece
160	Articles published in the popular	DEMOCRITUS UNIVERSITY	European Space Internetworking Center in	23/06/2012	IMERISIA newspaper	Medias	15000	Greece

	<i>press</i>	OF THRACE	Xanthi					
161	<i>Articles published in the popular press</i>	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	11/06/2014	Xanthipress.gr	Civil society - Medias	2000	Greece
162	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Internet is extended to Space	12/10/2010	Athens News Agency (http://walking-greece.ana-mpa.gr/articleview2.php?id=11555)	Medias	9000	Greece
163	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	01/11/2010	Real FM radio	Civil society	9000	Greece
164	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	European Space Internetworking Center in Xanthi	01/11/2010	"Innovation, research and technology" magazine (http://www.ekt.gr/content/img/product/82356/6-11.pdf)	Scientific community (higher education, Research) - Industry - Policy makers	3000	Greece
165	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	18/11/2010	Xronos FM	Civil society	250	Greece
166	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	European Space Internetworking Center in Xanthi	28/02/2011	"Research and innovation" e-newsletter	Scientific community (higher education, Research) - Industry - Policy makers	3000	Greece
167	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Interview on Space Internetworking Cente	16/09/2012	Second Radio Station of the Hellenic Broadcast Corporation	Medias	5000	Greece
168	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	11/06/2014	Channel 6 (https://www.youtube.com/watch?v=xQf7YZIjIfU&index=89)	Civil society - Medias	N/A	Greece
169	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Young researchers in Greece	29/04/2014	Epixeiro.gr	Civil society - Medias	N/A	Greece
170	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Young researchers in Greece	20/04/2014	ADORE Magazine	Civil society - Medias	N/A	Greece
171	<i>Interviews</i>	DEMOCRITUS UNIVERSITY OF THRACE	Greece conquers Space!	24/10/2013	Provocateur.gr (http://provocateur.gr/post/200/h-allh-ellada-hellip-ayth-poy-katakta-to-diasthma)	Civil society - Medias	N/A	Greece

172	Interviews	DEMOCRITUS UNIVERSITY OF THRACE	Large scale attack on SOHO routers	05/03/2014	TORA TV show (http://www.skai.gr/tv/show/?showid=65576)	Civil society - Medias	N/A	Greece
173	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	30/09/2010	AGONAS newspaper (http://www.empros.xan.gr/index.php?pg=2&id=370973)	Civil society - Medias	100	Greece
174	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	30/09/2010	EMPROS newspaper (http://www.empros.xan.gr/index.php?pg=2&id=370973)	Civil society - Medias	100	Greece
175	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	30/09/2010	Xronos newspaper (http://www.xronos.gr/detail.php?ID=60254)	Civil society - Medias	120	Greece
176	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	07/10/2010	Thraki Live Blog (http://thrakilive.blogspot.gr/2010/10/blog-post_2183.html)	Civil society	35	Greece
177	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	12/10/2010	Nooz portal (http://www.nooz.gr/science/to-diadiktuo-epekteinetai-kai-sto-diastima)	Civil society	60	Greece
178	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center founded in Xanthi	12/10/2010	Ikypros portal (http://www.ikypros.com/easyconsole.cfm/id/3455)	Civil society	200	Greece, Cyprus
179	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Internet is extended to Space	12/10/2010	TVXS portal (http://tvxs.gr/news/scitech/το-διαδίκτιο-επεκτείνεται-στο-διάστημα)	Civil society	1000	Greece
180	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	28/02/2011	National Documentation Center (http://www.ekt.gr/content/display?prnbr=82653)	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	150	Greece
181	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Internet from Thrace to Space	13/03/2011	Evros-Line portal (http://evros-line.blogspot.com/2011/03/blog-post_2079.html)	Civil society	40	Greece
182	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	European Space Internetworking Center in Xanthi	17/03/2011	Edugate.gr portal	Scientific community (higher education, Research) - Civil society	200	Greece
183	Press releases	DEMOCRITUS	Two-day workshop on Space	03/09/2011	Foititiko.gr	Civil society	N/A	Greece

		UNIVERSITY OF THRACE	Internetworking		(http://foititikocafe.gr/2011/09/03/spice-center/)			
184	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	08/06/2014	Xanthipress.gr	Civil society	N/A	Greece
185	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	12/06/2014	Adesmeuti Newspaper (http://adesmeuti-thrakis.blogspot.gr/2014/06/blog-post_3704.html)	Civil society	N/A	Greece
186	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	05/06/2014	Empros Newspaper (http://www.frontpages.gr/d/20140605/410/Εμπρός)	Civil society - Medias	N/A	Greece
187	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	09/06/2014	ThrakiSports.gr	Civil society - Medias	N/A	Greece
188	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	10/06/2014	Seleo.gr (www.seleo.gr/voreia-ellada/139327-diastimiki-imerida-simera-stin-ksanthi#.U6rxHRZ9p-s)	Civil society - Medias	N/A	Greece
189	Press releases	DEMOCRITUS UNIVERSITY OF THRACE	Workshop on Space Internetworking in Xanthi	10/06/2014	Zougla.gr	Civil society	N/A	Greece
190	Posters	DEMOCRITUS UNIVERSITY OF THRACE	SPICE poster	10/09/2010	SPICE	Scientific community (higher education, Research) - Industry - Civil society	300	Worldwide
191	Posters	DEMOCRITUS UNIVERSITY OF THRACE	SPICE colloquium poster	15/09/2010	SPICE	Scientific community (higher education, Research)	30	Greece
192	Posters	DEMOCRITUS UNIVERSITY OF THRACE	SPICE poster for the organised workshop	22/08/2011	SPICE	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	250	Greece
193	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Poster for the "Delay- and Disruption- Tolerant Networks (DTNs) workshop"	21/05/2012	Santorini, Greece	Scientific community (higher education, Research)	400	Worldwide
194	Posters	DEMOCRITUS UNIVERSITY	Space Internetworking Center banners	01/06/2014	Space Internetworking Center	Scientific community (higher education, Research) - Civil	N/A	Worldwide

		OF THRACE				society - Medias		
195	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Bundle Streaming Service	30/03/2013	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
196	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Space Internetworking Center	30/03/2013	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias	N/A	Worldwide
197	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Traffic Shaping for Enabling Less-than-Best Effort Services at the Edges of Broadband Connections	20/09/2013	ACM MobiCom Workshop on Lowest Cost Denominator Networking for Universal Access, LCDNet '13	Scientific community (higher education, Research)	N/A	Worldwide
198	Posters	DEMOCRITUS UNIVERSITY OF THRACE	JDTN: A Java API for ION DTN implementation	30/03/2013	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
199	Posters	DEMOCRITUS UNIVERSITY OF THRACE	CARPOOL: Connectivity Plan Routing Protocol	20/09/2013	ACM MobiCom Workshop on Lowest Cost Denominator Networking for Universal Access, LCDNet '13	Scientific community (higher education, Research)	N/A	Worldwide
200	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Bundle Delivery Time Estimation tool	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
201	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Delay Tolerant Payload Conditioning Protocol	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
202	Posters	DEMOCRITUS UNIVERSITY OF THRACE	SPICE Testbed: A DTN Testbed for Satellite and Space Communications	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
203	Posters	DEMOCRITUS UNIVERSITY OF THRACE	Space Data Routers for the dissemination and exploitation of space data	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research) - Industry - Policy makers	N/A	Worldwide
204	Posters	DEMOCRITUS UNIVERSITY OF THRACE	DTN Sensor Data Carrier	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research)	N/A	Worldwide
205	Posters	DEMOCRITUS UNIVERSITY	Application of a BitTorrent-like Data Distribution Model to	15/05/2014	Space Internetworking Center	Scientific community (higher education, Research) -	N/A	Worldwide

		<i>OF THRACE</i>	<i>Mission Operations</i>			<i>Industry</i>		
206	<i>Posters</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>NS2 DTN Agent</i>	<i>15/05/2014</i>	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research)</i>	<i>N/A</i>	<i>Worldwide</i>
207	<i>Flyers</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>SPICE: Space Internetworking Center</i>	<i>28/05/2012</i>	<i>Delay- and Disruption- Tolerant Networks (DTNs) workshop, Santorini, Greece</i>	<i>Scientific community (higher education, Research)</i>	<i>60</i>	<i>Worldwide</i>
208	<i>Flyers</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>Space Internetworking Center info</i>	<i>18/06/2013</i>	<i>Space Internetworking Center</i>	<i>Scientific community (higher education, Research) - Civil society</i>	<i>N/A</i>	<i>Greece</i>
209	<i>Flyers</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>Space Internetworking Center info</i>	<i>10/06/2014</i>	<i>Elisso Hotel, Xanthi, Greece</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	<i>100</i>	<i>Greece</i>
210	<i>Flyers</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>Space Internetworking Center triptych</i>	<i>10/06/2014</i>	<i>Elisso Hotel, Xanthi, Greece</i>	<i>Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias</i>	<i>100</i>	<i>Greece</i>
211	<i>Presentations</i>	<i>DEMOCRITUS UNIVERSITY OF THRACE</i>	<i>Enabling Free Internet Access at the Edges of Broadband Connections</i>	<i>29/05/2014</i>	<i>Aristotle University of Thessaloniki, Greece</i>	<i>Scientific community (higher education, Research)</i>	<i>8</i>	<i>Greece</i>

LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.

Type of IP Rights ¹⁰ :	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
-	-	-	-	-	-

Type of Exploitable Foreground <small>13</small>	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date <small>dd/mm/yyyy</small>	Exploitable product(s) or measure(s)	Sector(s) of application ¹⁴	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
<i>General advancement of knowledge</i>	<i>Delay Tolerant Payload Conditioning Protocol</i>	<i>No</i>	<i>None</i>	<i>Delay Tolerant Payload Conditioning Protocol</i>	<i>Academic research</i>	<i>N/A</i>	<i>N/A</i>	<i>SPICE & JPL</i>
<i>General advancement of knowledge</i>	<i>Bundle Delivery Time Estimation tool</i>	<i>No</i>	<i>None</i>	<i>Bundle Delivery Time Estimation tool</i>	<i>Academic research</i>	<i>N/A</i>	<i>N/A</i>	<i>SPICE & JPL</i>
<i>General advancement of knowledge</i>	<i>Bundle Streaming Service</i>	<i>No</i>	<i>None</i>	<i>Bundle Streaming Service</i>	<i>Academic research</i>	<i>N/A</i>	<i>N/A</i>	<i>SPICE & JPL</i>
<i>General advancement of knowledge</i>	<i>NS2 DTN Agent</i>	<i>No</i>	<i>None</i>	<i>NS2 DTN Agent</i>	<i>Academic research</i>	<i>N/A</i>	<i>N/A</i>	<i>SPICE</i>
<i>General advancement of knowledge</i>	<i>Contact Plan Update Protocol</i>	<i>No</i>	<i>None</i>	<i>Contact Plan Update Protocol implementation</i>	<i>Space Missions configuration</i>	<i>N/A</i>	<i>N/A</i>	<i>SPICE</i>

Delay Tolerant Payload Conditioning Protocol (DTPC):

Description

Delay Tolerant Payload Conditioning (DTPC) protocol is a transport layer protocol which extends the DTN architecture in a fashion that accords with the end-to-end principle, enabling the following services: (a) application data aggregation, (b) application-level reliability, (c) in-order delivery, and (d) duplicate suppression.

Its purpose

DTPC protocol offers a “safety-net” that assures end-to-end data delivery even if the underlying reliability mechanisms of DTN architecture fail, an efficient bandwidth optimization service based on data aggregation techniques that can achieve significant reduction in bandwidth consumption, and enables end-to-end application-oriented services, such as in-order delivery and duplicate suppression, which are vital for the efficient operation of many types of DTN applications

How the foreground might be exploited, why and by whom

DTPC protocol can be exploited as a communication enhancement by Aircraft, Space and military industrial organizations, as well as by Space agencies such as ESA and NASA.

Possible market applications

DTPC protocol can be employed to any space and terrestrial DTN-based network for enhancing network reliability and improving the performance of continuous situational-awareness, telemetry and sensor applications.

Stage of development

DTPC protocol is fully functional. Standardization by the Consultative Committee for Space Data Systems (CCSDS) is in progress and will be completed on Fall 2014.

Further research necessary, if any

None

Collaboration sought or offered

A number of collaboration opportunities with researchers wishing to extend protocol's functionality.

Potential/expected impact (quantify where possible)

DTPC offers a new perspective on the design of delay tolerant networks which incorporates a true transport layer within the DTN architecture for providing application-oriented end-to-end services.

Intellectual property rights

Open source package with a free-to-use license for non-commercial use. The intellectual property rights for commercial use are tackled within respective license agreements between

Space Internetworking Center and Jet Propulsion laboratory. The two entities are currently the sole holders of the intellectual property rights for commercial use.

IPR exploitable measures taken or intended

No measures are taken so far.

Bundle Delivery Time Estimation (BDTE) tool:

Description

BDTE is an administrative network simulation tool that applies the Contact Graph Routing algorithm on every network node throughout the route of the bundle. The BDTE algorithm performs hop-by-hop simulations, provides possible arrival times for each hop, and continues iteratively through the entire predicted bundle route, which ultimately results in the arrival time at the final destination. The calculated latency for each hop is based on deterministic and stochastic latency components. The former comprises propagation delay (also referred to as one-way-light-time or OWLT) and transmission delay for bundle delivery (including overhead) via the link channel, i.e., the length of time that will be required simply to transmit the bundle given the maximum transmission rate on the link. The stochastic component is introduced by uncorrected channel errors, which compel packet retransmissions; it accounts for the propagation and transmission delay for retransmitted packets.

Its purpose

Based on the SISG operations concept for the Solar System Internet (SSI), BDTE purpose in twofold: 1. Timeliness: The network shall allow timely delivery, as required by the user, via managing the timing for delivery of the forward link product. Users will need to know the predicted epoch by which a given forward product will reach the destination node.

2. Predictability: It shall be possible to identify all provider components' latency and the resulting earliest/latest physical delivery times under normal conditions of SSI network operation.

How the foreground might be exploited, why and by whom

BDTE can be used for administrative purposes and can provide time delivery expectations for critical bundles. The earliest plausible delivery times may also be computed, and delivery probabilities prior to a given time in the future may be provided. Therefore, BDTE could provide a useful administrative tool to predict the performance of different space applications and adjust their functionality and usage in real-time. It might be exploited by Space Agencies and Principal Investigators in Space and satellite applications and services.

Possible market applications

The possible market target includes Space Agencies, operators of space and satellite services (i.e., earth observation, file transmissions, etc.)

Stage of development

Initial prototype developed and tested together with the open source Interplanetary Overlay Network DTN implementation.

Further research necessary, if any

N/A

Collaboration sought or offered

Exploitation of network statistics in space nodes, and collaboration with DTN Network Management Protocol, which is upon standardisation.

Potential/expected impact (quantify where possible)

Upon open source release of the application, all agencies and partners participating in Consultative Committee for Space Data Systems (CCSDS) will be informed and they will be able to exploit the application in future tests and operations.

Intellectual property rights

Open source software license.

IPR exploitable measures taken or intended

Under discussion with JPL. It will probably be released under BSD open source software license, either as a standalone application or as part of the ION-DTN software distribution.

Bundle Streaming Service (BSS):**Description**

Bundle Streaming Service (BSS) is a communication framework that enables 'streaming' data to be conveyed via DTN 'bundles' in a manner that supports in-order stream processing with minimal latency while ensuring at the same time reliable delivery of data.

Its purpose

BSS improves the reception and storage of data streams through the application of sophisticated forwarding tactics and the exploitation of inherent delay/disruptive tolerant networking (DTN) architecture features. It also provides ad-hoc 'playback' review of recently received information.

How the foreground might be exploited, why and by whom

Bundle Streaming Service can be exploited as a communication framework by various industrial organizations involved in the Aerospace, Space and military industry, as well as from Space agencies such as ESA and NASA.

Possible market applications

Bundle Streaming service can be employed for improving the performance of various real-time network applications including one-way voice, video or continuous telemetry streaming.

Stage of development

Bundle streaming service is fully functional now.

Further research necessary, if any

N/A

Collaboration sought or offered

Information exchange with network researchers.

Potential/expected impact (quantify where possible)

The DTN working group of the Consultative committee for Space Data Systems (CCSDS) is considering the possibility of testing the Bundle Streaming Service for transmitting streaming data from the International Space Station to Earth within the next years

Intellectual property rights

Open source package with a free-to-use license for non-commercial use. The intellectual property rights for commercial use are tackled within respective license agreements between Space Internetworking Center and Jet Propulsion laboratory. The two entities are currently the sole holders of the intellectual property rights for commercial use.

IPR exploitable measures taken or intended

No measures are taken so far.

NS2 DTN Agent:**Description**

The DTN Agent is a simulation model that facilitates detailed experimentation with DTN in the ns-2 network simulator environment. It is implemented as a subclass of the Agent class and, in a fashion similar to other agents, can be attached to an ns-2 node as well as a source or a sink application. A single type of a DTN Agent is used for all purposes (i.e. as a source, relay, or destination), and it supports both TCP and UDP convergence layers. When the TCP convergence layer is used a special pair of source and sink TCP classes is employed, while when the UDP convergence layer is used a customized UDP class is employed.

Its purpose

The model was created in order to study the deployment of DTN as an overlay on top of a number of different underlying technologies, ranging from traditional, Internet-based networks (possibly containing a last hop wireless link) to space networks.

How the foreground might be exploited, why and by whom

Experimenting with the DTN Agent can provide useful insight into many of the Bundle Protocol design details such as: custody acceptance and rejection reporting, routing strategies, retransmission timeouts, and bundle fragmentation. Additionally, the model facilitates experimentation with issues related to storage management and storage occupancy distribution on the network path. The Agent can be used by researchers studying various aspects of DTN as well as network operators and space agencies wishing to evaluate certain network deployment scenarios.

Possible market applications

The software is a research tool and, as such, it has limited marketing potential.

Stage of development

The software is fully functional. It can be extended depending on the occasion and the needs of each user.

Further research necessary, if any

Further research may involve functionality that enables experimenting with DTN in a dynamically changing network topology.

Collaboration sought or offered

A number of collaboration opportunities with researchers wishing to experiment on related topics have emerged.

Potential/expected impact (quantify where possible)

The software is expected to assist in providing supporting simulation for a number of DTN-related research topics.

Intellectual property rights

The software is freely distributed.

IPR exploitable measures taken or intended

Not applicable.

Contact Plan Update Protocol:

Description

Contact Plan Update Protocol (CPUP) is a dynamic update protocol responsible for the dissemination of knowledge that pertains to dynamic network features and parameter changes. In particular it resides on top of the Bundle Protocol to transmit information about the network transmission opportunities, also termed as contacts. The contact information updates can contain values such as start time, end time, from node, to node, transmission rate, one-way-

light-time, etc. The creation and transmission of a CPUP protocol data unit can be initiated manually, i.e., at an administrative basis, or automatically, using a daemon that generates update messages when specific facts are triggered.

Its purpose

CPUP main purpose is to disseminate information about contact plan updates, such as new transmission opportunities, and dynamically update queueing backlog information and link disruptions.

How the foreground might be exploited, why and by whom

CPUP can be exploited by the space agencies in future space internetworks with connectivity based on Contact Plan information. It can provide a framework to update the network connectivity plan, by generating information about new contacts, or by modifying or deleting already existing contacts.

Possible market applications

The possible market target includes Space Agencies, and operators of space and satellite services.

Stage of development

CPUP was designed and initially described in a scientific paper published in the proceedings of Chants 2013 workshop. The timeline of its development is currently under discussion.

Collaboration sought or offered

During the standardization procedures, collaboration will be sought with NASA's team that develops DTN Management Protocol standard, since the two protocols have a possible overlap.

Potential/expected impact (quantify where possible)

CPUP development will possibly impact the space community.

Intellectual property rights

N/A

IPR exploitable measures taken or intended

N/A

4.3 Report on societal implications

A General Information *(completed automatically when Grant Agreement number is entered.*

Grant Agreement Number:	264226
Title of Project:	Space Internetworking Center
Name and Title of Coordinator:	Prof. Vassilis Tsaoussidis

B Ethics

<p>1. Did your project undergo an Ethics Review (and/or Screening)?</p> <ul style="list-style-type: none"> If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? <p>Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 'Work Progress and Achievements'</p>	NO
<p>2. Please indicate whether your project involved any of the following issues (tick box) :</p>	NO
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	

• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	
• Research having the potential for terrorist abuse	

C Workforce Statistics		
3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).		
Type of Position	Number of Women	Number of Men
Scientific Coordinator		1
Work package leaders		3
Experienced researchers (i.e. PhD holders)	1	11
PhD Students		5
Other	3	4
4. How many additional researchers (in companies and universities) were recruited specifically for this project?		17
Of which, indicate the number of men:		13

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	<input checked="" type="radio"/> <input type="radio"/>	Yes No
6. Which of the following actions did you carry out and how effective were they?		
	Not at all effective	Very effective
■ Design and implement an equal opportunity policy	○ ○ ○ ○ ○	○ ○ ○ ○ <input checked="" type="radio"/>
□ Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○	○ ○ ○ ○ ○
□ Organise conferences and workshops on gender	○ ○ ○ ○ ○	○ ○ ○ ○ ○
■ Actions to improve work-life balance	○ ○ ○ ○ ○	○ ○ ○ ○ <input checked="" type="radio"/>
○ Other:		
7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?		
○ Yes- please specify		
<input checked="" type="radio"/> No		

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- Yes- please specify
- No

- Organisation of a colloquium open to all interested parties on a regular basis
- Organisation of a Distinguished Speaker Series with invited speakers from other universities/institutes
- Organisation of three workshops within the framework of the project that attracted the interest of students of the Democritus University of Thrace

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- Yes- please specify
- No

- Set up and maintenance of project website that is constantly updated
- Publication of the tri-annual “SPICE Update” newsletter
- Production of a “Project Activity Summary” book that summarizes all activities that took place within the framework of SPICE project
- Creation of a promotional video for SPICE

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- | | |
|--|--|
| <input checked="" type="radio"/> Main discipline ²⁰ : 1.1 | |
| <input checked="" type="radio"/> Associated discipline ¹⁷ : 2.2 | <input checked="" type="radio"/> Associated discipline ¹⁷ : 1.4 |
| <input checked="" type="radio"/> Associated discipline ¹⁷ : 1.2 | <input checked="" type="radio"/> Associated discipline ¹⁷ : 2.3 |

²⁰ Insert number from list below (Frascati Manual).

G Engaging with Civil society and policy makers	
11a Did your project engage with societal actors beyond the research community? <i>(if 'No', go to Question 14)</i>	<input type="radio"/> Yes <input checked="" type="radio"/> No
11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?	
No Yes- in determining what research should be performed Yes - in implementing the research Yes, in communicating /disseminating / using the results of the project	
11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	<input type="radio"/> Yes <input type="radio"/> No
12. Did you engage with government / public bodies or policy makers (including international organisations)	
No Yes- in framing the research agenda Yes - in implementing the research agenda Yes, in communicating /disseminating / using the results of the project	
13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?	
Yes – as a primary objective (please indicate areas below- multiple answers possible) Yes – as a secondary objective (please indicate areas below - multiple answer possible) No	
13b If Yes, in which fields?	
Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs	Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid
	Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport
13c If Yes, at which level?	
Local / regional levels National level European level International level	

H Use and dissemination		
14. How many Articles were published/accepted for publication in peer-reviewed journals?	11	
To how many of these is open access²¹ provided?	3	
How many of these are published in open access journals?		
How many of these are published in open repositories?		
To how many of these is open access not provided?	8	
Please check all applicable reasons for not providing open access:		
<input checked="" type="checkbox"/> publisher's licensing agreement would not permit publishing in a repository <input type="checkbox"/> no suitable repository available <input type="checkbox"/> no suitable open access journal available <input type="checkbox"/> no funds available to publish in an open access journal <input type="checkbox"/> lack of time and resources <input type="checkbox"/> lack of information on open access <input type="checkbox"/> other ²² :		
15. How many new patent applications ('priority filings') have been made? <i>("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).</i>	None	
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	None
	Registered design	None
	Other	
17. How many spin-off companies were created / are planned as a direct result of the project?	None	
<i>Indicate the approximate number of additional jobs in these companies:</i>		
18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:		
<input checked="" type="checkbox"/> Increase in employment, or <input type="checkbox"/> Safeguard employment, or <input type="checkbox"/> Decrease in employment, <input type="checkbox"/> Difficult to estimate / not possible to quantify	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	In small & medium-sized enterprises In large companies None of the above / not relevant to the project
19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs:	<i>Indicate figure:</i> 18.5	

²¹ Open Access is defined as free of charge access for anyone via Internet.

²² For instance: classification for security project.

Difficult to estimate / not possible to quantify



I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

Yes No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

Yes No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

- | | |
|--|--|
| <input type="checkbox"/> Press Release | <input type="checkbox"/> Coverage in specialist press |
| <input type="checkbox"/> Media briefing | <input type="checkbox"/> Coverage in general (non-specialist) press |
| <input type="checkbox"/> TV coverage / report | <input type="checkbox"/> Coverage in national press |
| <input type="checkbox"/> Radio coverage / report | <input type="checkbox"/> Coverage in international press |
| <input type="checkbox"/> Brochures /posters / flyers | <input type="checkbox"/> Website for the general public / internet |
| <input type="checkbox"/> DVD /Film /Multimedia | <input type="checkbox"/> Event targeting general public (festival, conference, exhibition, science café) |

23 In which languages are the information products for the general public produced?

- | | |
|--|---|
| <input type="checkbox"/> Language of the coordinator | <input checked="" type="checkbox"/> English |
| <input type="checkbox"/> Other language(s) | |

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

- 1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
- 1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
- 1.3 Chemical sciences (chemistry, other allied subjects)
- 1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
- 1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2. ENGINEERING AND TECHNOLOGY

- 2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
- 2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
- 2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

- 3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
- 3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
- 3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

- 4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
- 4.2 Veterinary medicine

5. SOCIAL SCIENCES

- 5.1 Psychology
- 5.2 Economics
- 5.3 Educational sciences (education and training and other allied subjects)
- 5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary, methodological and historical SIT activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

- 6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
- 6.2 Languages and literature (ancient and modern)
- 6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other SIT activities relating to the subjects in this group]