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SPICE

progress per

Work

Package

The project is conducted in four separate work packages.

Work Package 2:

Exchange of know-how and recruitment of researchers and administrative staff

Within the framework of the Distinguished Speaker Series, two presentations were organised at the premises of SPICE. On February 24th, Dr Athanasia Tsertou from the Institute of Communication and Computer Systems, Athens, Greece, gave an insight to Smart Cyber Physical Systems. On March 17th, Dr Stratos Kontopoulos, from Informatics and Telematics Institute (ITI) of the Center for Research and Technology, Hellas (CERTH), Greece, presented ways to

deploy defeasible logics in the Semantic Web.

Work Package 3:

Infrastructure update and state-of-the-art DTN testbed

The research paper "SPICE testbed: A DTN testbed for satellite and space communications has been accepted for publication at the 9th International Conference on Testbeds and Research Infrastructures for the Development and Communities (TRIDENTCOM'14).

Work Package 4:

Exploitation and dissemination

As part of WP4, SPICE researchers presented their latest research achievements to the NETSPACE workshop on Networking Technologies for Efficient Space Data Dissemination and Exploitation and the 11th IEEE/IFIP Annual Conference on Wireless On-Demand Network Systems and Services (WONS 2014). Moreover, Prof. Tsaoussidis participated in the CCSDS Spring meeting series that took place in Netherlands and SPICE staff member Ioannis Komnios participated in the 1st Global Access to the Internet for All (GAIA) IRTF group meeting that took place in London in March 2014.



What is HORIZON 2020?

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.

Horizon 2020 is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness.

Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament. They agreed that research is an investment in our future and so put it at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs.



By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

Horizon 2020 is open to everyone, with a simple structure that reduces red tape and time so participants can focus on what is really important. This approach makes sure new projects get off the ground quickly – and achieve results faster.

The EU Framework Programme for Research and Innovation will be complemented by further measures to complete and further develop the European Research Area. These measures will aim at breaking down barriers to create a genuine single market for knowledge, research and innovation.



HORIZON 2020

The EU Framework Programme for Research and Innovation

SPICE DTN testbed

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:

- *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.
- *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.
- *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 standardised protocols and perform interoperability testing.
- *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

SPICE DTN testbed

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.

The main rack of the testbed and the overall architecture of SPICE DTN testbed are depicted.

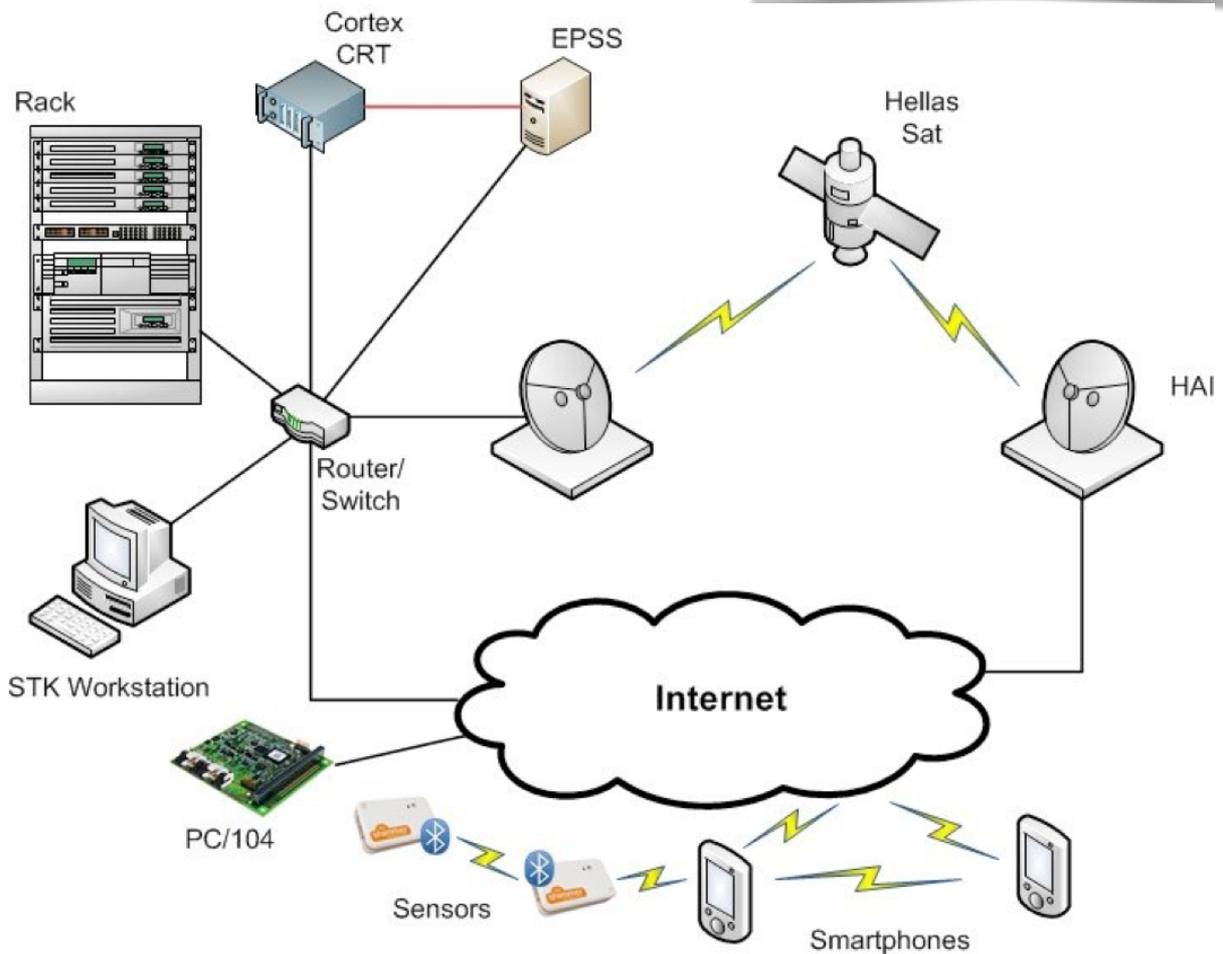


Fig. SPICE testbed diagram



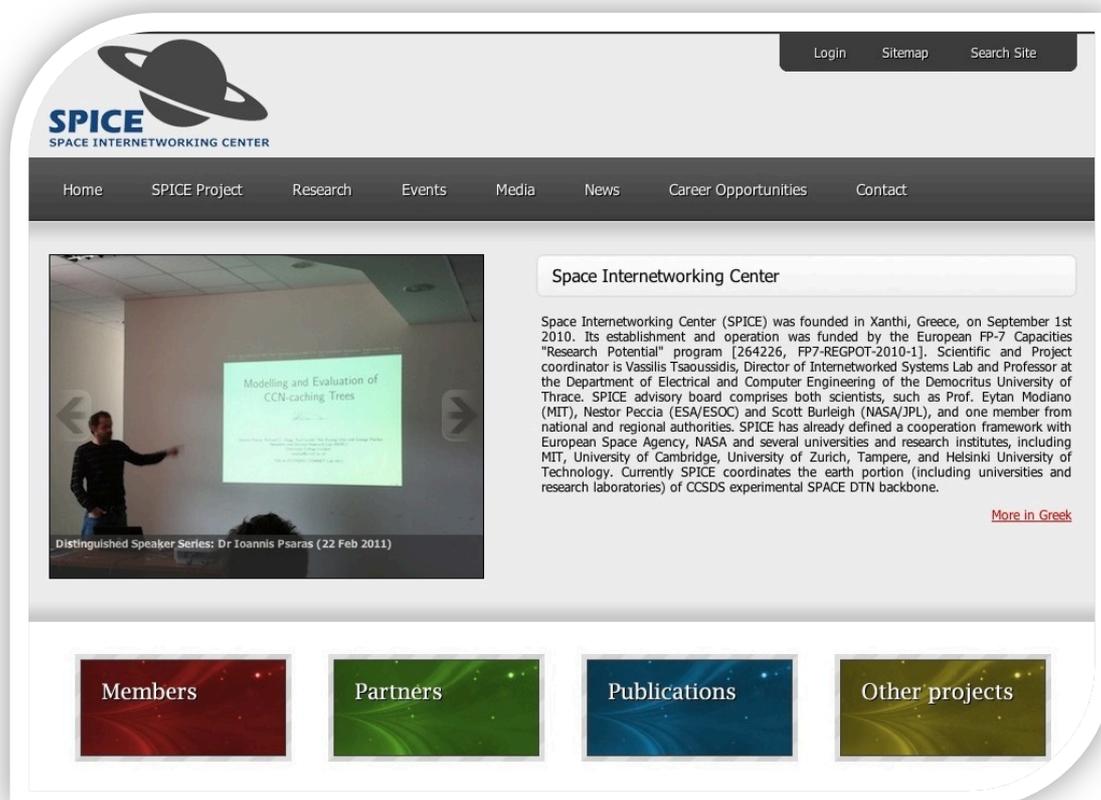
SPICE Newsletter and Website

Space Internetworking Center (SPICE) website can be found at:

www.spice-center.org

Here you will find:

- ❖ Previous issues of SPICE Update newsletter
- ❖ A comprehensive overview of the project, including details about partners and the various work packages
- ❖ Information on Space Internetworking Center, research interests and members
- ❖ Event information – a complete list of lectures, colloquia and relative events
- ❖ Publications



Contact Plan Update Protocol (CPUP)

Nikos Bezirgiannidis

Interplanetary communications are characterized by long propagation delays and intermittent but scheduled connectivity. In this context, Delay-Tolerant Networking (DTN) has been proposed as a perfect candidate to support communications in Space in the future. Indeed, based on an end-to-end, store-and-forward architecture, DTN can naturally unify intra-planetary, deep space, near-Earth and terrestrial communications, forming a flexible and secure networking overlay.

Despite the deterministic nature of scheduled interplanetary communications there are still cases where unexpected disruptions or dynamic parameters of probabilistic nature such as queueing delay may drift the scheduled communication map. This calls for improved and up-to-date network information. This, in turn, requires enhancements on the routing algorithm to integrate the dynamic network parameters.

Although network dynamics can be observed and communicated centrally by space agencies, long propagation delays may render this information obsolete by the time it reaches remote space assets. A distributed, automated update mechanism, instead, based on information created and disseminated by all relevant space assets, could prove itself more beneficial in Space. This statement

can only be justified if such knowledge can lead to more accurate data delivery estimations, improved routing decisions and, consequently, shorter delivery times.

In this context, we propose a dynamic framework to improve accuracy and flexibility in space communications. This framework consists of: i) a mechanism that incorporates queueing delay and possible disruptions to calculate the *Earliest Transmission Opportunity (ETO)*; this allows for determining the shortest route between any two assets, and ii) an update protocol, namely *Contact Plan Update Protocol (CPUP)*, for the dissemination of knowledge that pertains to dynamic network features and parameter changes.

Contact Graph Routing uses predefined contact schedules that every network node is assumed to have. ECGR, in particular, examines all available paths to destination and concludes on an optimal path based on the earliest arrival time; it does not, however, include queueing delay information in the total delivery latency.

To measure and further incorporate queueing delay into the network contact plan, we define *ETO* as the earliest plausible time within a transmission opportunity to forward a bundle with a certain priority. *ETO* has dual applicability: it measures the

Contact Plan Update Protocol (CPUP)

Nikos Bezirgiannidis

occupancy in specific outducts, while in parallel it can efficiently encode a link disruption. *ETO* values range from the contact start time, which is set as the default and minimum value, up to the contact end time, which is set as the maximum value. Different priority levels are reflected in corresponding *ETO* parameters for each transmission opportunity. In BP, for example, the three priority levels defined are bulk, normal, and expedited.

Unlike the already existing ECGR, the proposed algorithm CGR-ETO substitutes the contact start time with *ETO* to calculate the earliest arrival time, during contact graph traversals. This way it incorporates both the most recent available queueing information, for the given bundle priority, and potential notifications about link outages.

With regard to queueing information, *ETO* is updated after routing decisions are made in the local node and/or upon reception of CPUP messages from other nodes. In the former case, when a bundle is routed and inserted in an outbound queue towards a neighboring node, the local node increases the corresponding *ETO* for the specific transmission opportunity during which bundle transmission is expected to occur. The *ETO* parameter is updated for all priority levels equal to or lower than the priority level of the bundle to be transmitted. In the latter case, upon the reception of a CPUP message containing *ETO* information about specific contacts, the local node updates its contact plan accordingly. In the same way, information about an outage can be encoded by an *ETO* increase.

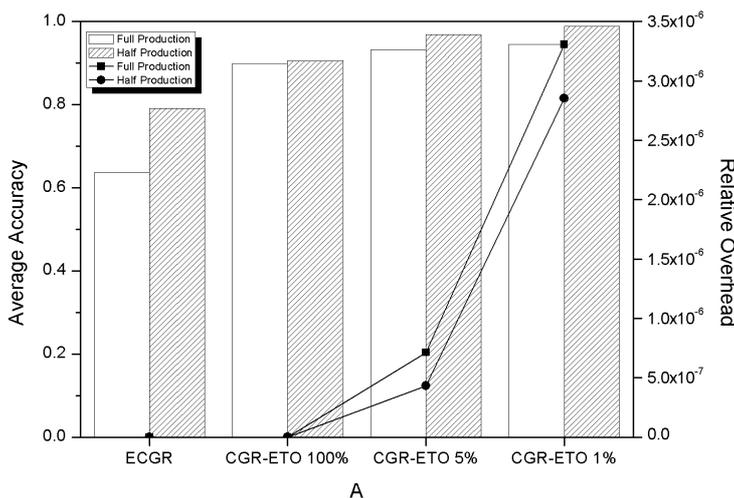


Figure. Average Bundle Delivery Delay Prediction Accuracy and Relative Overhead for full and half data production, for different levels of CPUP update threshold

Simulations show that our framework has the potential to improve routing decisions; we demonstrated significant delivery delay reduction in heavy-traffic scenarios and we observed similar behavior in disruptive environments. The improvement is more significant, when there is an alternative link and occasionally when disruptions appear later in the transmission window. It is worth noticing that delay prediction accuracy undoubtedly improves, irrespectively of the particular conditions of each scenario.

- L. Mamatas, A. Papadopoulou and V. Tsaoussidis, "**Semi Markov modeling for User Mobility in Urban Areas**", 2nd Stochastic Modeling Techniques and Data Analysis International Conference (SMTDA 2012), Chania, Greece, June 5-8, 2012
- G. Papastergiou, N. Bezirgiannidis and V. Tsaoussidis, "**On the Performance of Erasure Coding over Space DTNs**", 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012), Santorini, Greece, June 6-8, 2012.
- F. Tsapeli and V. Tsaoussidis, "**Routing for Opportunistic Networks Based on Probabilistic Erasure Coding**", 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012), Santorini, Greece, June 6-8, 2012.
- D. Vardalis and V. Tsaoussidis, "**Achieving energy-efficient with DTN: A Proof-of-concept and roadmap study**", 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012), Santorini, Greece, June 6-8, 2012.
- S.-A. Lenas, S. C. Burleigh and V. Tsaoussidis, "**Reliable Data Streaming over Delay Tolerant Networks**", 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012), Santorini, Greece, June 6-8, 2012.
- E. Katsiri, "**Cirrus: A Disruption-Tolerant Cloud**", 10th International Conference on Wired/Wireless Internet Communications (WWIC 2012), Santorini, Greece, June 6-8, 2012.
- R. Dunaytsev, D. Moltchanov, Y. Koucheryavy, O. Strandberg and H. Flinck, "**A Survey of P2P Traffic Management Approaches: Best Practices and Future Directions**", Journal of Internet Engineering, Klidarithmos Press, Volume 5, Number 1, 2012.
- N. Bezirgiannidis, S. Burleigh and V. Tsaoussidis, "**Delivery Time Estimation for Space Bundles**", Aerospace and Electronic Systems, IEEE Transactions on, vol.49, no.3, pp.1897-1910, July, 2013.

- I. Komnios and V. Tsaoussidis, "**CARPOOL: Extending Free Internet Access over DTN in Urban Environments**", ACM Mobicom workshop on Lowest Cost Denominator Networking for Universal Internet Access, LCDNET '13, Miami, Florida, USA, September 30, 2013.
- S.-A. Lenas and V. Tsaoussidis, "**Traffic Shaping for Enabling Less-than-Best Effort Services at the Edges of Broadband Connections**", ACM Mobicom workshop on Lowest Cost Denominator Networking for Universal Internet Access, LCDNET '13, Miami, Florida, USA, September 30, 2013.
- N. Bezirgiannidis, F. Tsapeli, S. Diamantopoulos and V. Tsaoussidis, "**Towards Flexibility and Accuracy in Space DTN Communications**", 8th ACM MobiCom Workshop on Challenged Networks, CHANTS '13, Miami, Florida, USA, September 30, 2013.
- D. Vardalis and V. Tsaoussidis, "**Exploiting the potential of DTN for energy-efficient internetworking**", Journal of Systems and Software, January 2014.
- G. Papastergiou, I. Alexiadis, S. Burleigh and V. Tsaoussidis, "**Delay Tolerant Payload Conditioning Protocol**", Elsevier Computer Networks, Elsevier Computer Networks, vol. 59, pp.244-263, February 2014.
- S.-A. Lenas and V. Tsaoussidis, "**Enabling free internet access at the edges of broadband connections: a hybrid packet scheduling approach**", SIGMOBILE Mobile Computing and Communications Review (MC2R), Vol. 18, Issue 1, pp.55-63, Feb. 2014
- I. Komnios, A. Sathiaselan and J. Crowcroft, "**LEDBAT Performance in Sub-packet Regimes**", 11th IEEE/IFIP Annual Conference on Wireless On-Demand Network Systems and Services (WONS 2014), Obergurgl, Austria, April 2-4, 2014.
- I. Komnios, I. Alexiadis, N. Bezirgiannidis, S. Diamantopoulos, S.-A. Lenas, G. Papastergiou and V. Tsaoussidis, "**SPICE Testbed: A DTN Testbed for Satellite and Space Communications**", 9th International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities (TRIDENTCOM 2014), Guangzhou, China, May 5-7, 2014.

Complete list of publications can be found at SPICE website.



Upcoming Events

**SPICE Project Final Dissemination event
will take place in June 2014 in Xanthi**

**“Contact Plan Routing Protocol” to be presented at
the 12th International Conference on Wired and
Wireless Internet Communications**

**“Predicting Queueing Delays in Delay Tolerant
Networks with Application in Space” to be
presented at the 12th International Conference on
Wired and Wireless Internet Communications**

**European Geosciences Union General Assembly,
Vienna, Austria, April 27th- May 2nd 2014**

**Application of a BitTorrent-like Data Distribution
Model to Mission Project End, April 2014**

**Prof. V. Tsaoussidis and SPICE staff member
Sotirios-Angelos Lenas will visit the
Hong Kong University of Science and Technology**

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