



**SPICE**

SPACE INTERNETWORKING CENTER

# SPICE update

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SPICE Project Coordinator

*Prof. Vassilis Tsaoussidis*

*e-mail: vtsaousi@ee.duth.gr*

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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**

As part of SPICE Distinguished Speaker Series, Prof. Carlo Caini, Associate Professor of Telecommunications in the Department of Electrical, Electronic and Information Engineering of University of Bologna, Italy, gave a lecture to SPICE researchers on October 29<sup>th</sup>, 2013. The presentation was entitled "DTN LEO Satellite Communications through Ground Stations and GEO Relays: CGR effectiveness and limits". Prof. Caini discussed with the audience the limitations of Contact

Graph Routing protocol and proposed possible enhancements.

### **Work Package 3:**

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

Within the framework of WP3, SPICE researchers worked on a submission to the 9<sup>th</sup> International conference on testbeds and research infrastructures for the development of networks and communities, regarding the updated SPICE DTN testbed.

### **Work Package 4:**

#### **Exploitation and dissemination**

Within the last months, SPICE researchers presented their research achievements in the ACM MobiCom Workshop on Lowest Cost Denominator Networking for Universal Access (LCD-NET) and 9<sup>th</sup> ACM MobiCom Workshop on Challenged Networks (CHANTS). Moreover, SPICE researchers Ioannis Komnios and Nikos Bezirgiannidis visited University of Cambridge and University of Bologna, respectively, to work on joint publications. SPICE members also attended several HORIZON 2020 information days on the upcoming ICT, Space and Marie Skłodowska-Curie calls.



# Application of a BitTorrent-like data distribution model to Mission Operations

ESA-funded project

With the move towards extending IP networks into Space, there is now the opportunity to consider the use of well-established and mature Internet communication models for use in space missions. One of the most attractive of these models, particularly in terms of distributed and resilient data delivery, is a 'torrent'.

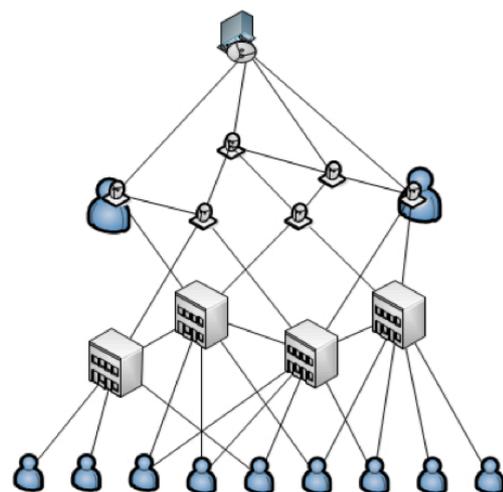
ESOC has recently taken final delivery of a complete implementation of the CCSDS File Delivery Protocol and, although it does not rely on IP networks (indeed, it is independent of underlying communication technologies), it does provide a set of services that could be used to implement a torrent-like distribution model.

The proposed network is an adaptation for LEO mission operations of the well-known Internet data distribution model using the CCSDS File Delivery Protocol. It is characterized by a high density VPN of mini/small (inexpensive) antennas on ground that act as peers in a network sharing data with the spacecraft, mission control centers and data subscribers, and spacecrafts that downlink over geographical regions rather than particular ground stations (see Figure below).

The objective of the project is to assess the technical feasibility, the capacity of data transfer and true compatibility with CFDP services of the space-ground and ground-ground communications. The study should in particular:

- Analyse the proposed concept and evolve its definition as required,
- Define a reference scenario and KPIs against which the model can be assessed,
- Specify the technical components of such a network,
- Perform dynamic simulations to assess the effectiveness of the model.

**The kick-off meeting of the project took place on October 23<sup>rd</sup>, 2013, in ESA/ESOC, Darmstadt, Germany.**



“The Internet is for everyone” claims Vint Cerf, the father of the Internet. His basic argument is that providing Internet access to underprivileged communities could have a huge positive social impact. From a networking perspective, this “Free Internet for All” notion could be realized by the exploitation of several existing resource pooling Internet technologies.

Broadband connection sharing constitutes one of those network resource-pooling techniques and its implementation can be based on User-Provided Networks (UPN). The concept of UPNs comprises two main entities: i) the micro-provider, which is the home-user or group of home-users that own the broadband connection and ii) the group of guest-users. Guest-users are often considered to be wireless connected users that need to freely access the Internet by exploiting the available unused capacity. Such a type of access could be implemented by mandating Less-than-Best-Effort (LBE) services, which provide lower access priority to the available resources compared to the standard Internet Best-Effort (BE) services offered to typical subscribers.

Although LBE service clearly corresponds to low-expected quality, it cannot be that low to violate the notion of service itself. Service in this case is the reason for the system to exist: no user, even free, would punish

himself by attempting to access a system repeatedly that will, likely, not work.

## **Assessing numerically the impact of LBE-traffic on BE-traffic**

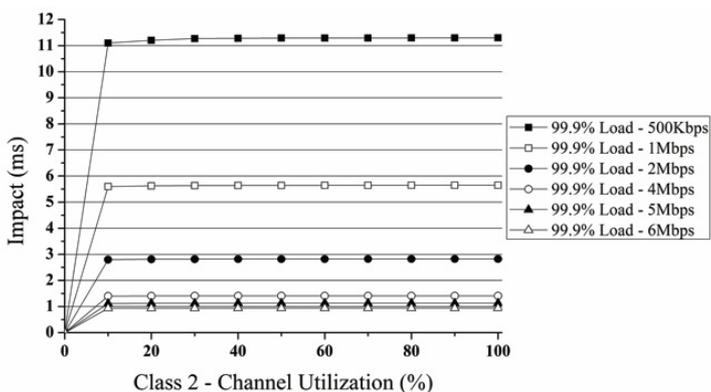
The majority of the already proposed queue-management techniques on LBE-traffic regulation in ADSL Access Points (APs) are proven to be suboptimal in several cases since they do not provide any quantitative characteristics of the additional imposed delay. Furthermore, results acquired through an extensive numerical analysis indicate that there is a certain bandwidth availability point over which the trade-off between allocating resources to serve LBE-traffic exclusively and increasing the impact on queuing delay for BE-traffic is efficiently balanced. As an example, for a target impact value of 1ms, this bandwidth availability point is estimated at 6 Mbps according to the results presented in the left Figure. Such a behavior constitutes a clear indication that over a low-bound value of bandwidth availability, a certain amount of bandwidth could be exclusively allocated to traffic class-2 (LBE-traffic), without having any major impact on traffic-class 1 (BE-traffic). This fact allows Priority Queuing-type schemes (PQ-schemes) to be replaced by Weighted Fair Queuing-type schemes (WFQ) in order to guarantee a certain level of service.

## Hybrid Packet Scheduling Scheme (HPSS)

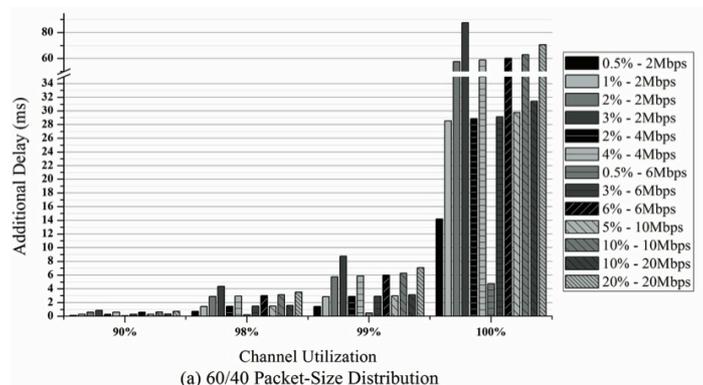
HPSS was proposed for enabling LBE service in the APs of UPNs in an efficient and highly scalable manner. It applies service differentiation on a per-packet basis and has two modes of operation. In the first mode, which is active when link speed is below a certain bandwidth availability point, the scheme applies a non-preemptive PQ policy between BE- and LBE-traffic. Unlike previous methods, the applied temporal-based packet scheduling approach confines the additional delay imposed on BE-traffic under a specific target value. For example, in case the additional delay of 3ms is considered insignificant, the results presented in the left Fig. prompt for a bandwidth availability point of 2Mbps. The second mode of operation is activated for link speeds over that

particular bandwidth availability point. In this mode, a class-based WFQ policy is applied, which allocates resources per class in order to guarantee a minimum service rate, as long as the total channel utilization is less than a certain limit (e.g. 98%). In case channel utilization exceeds that limit, the system cancels the CB-WFQ policy, and applies a non-preemptive PQ policy instead, to guarantee that the impact will not exceed a tolerable value.

The reasoning behind that strategy derives from the fact that the additional delay between applying a class-based WFQ and a PQ policy increases exponentially as channel utilization increases (right Fig.). In particular, the additional delay imposed to the average system time of traffic class-1 remains under tolerable levels for channel utilizations up to 98%.



**Left Fig.** Temporal impact of LBE-traffic over BE-traffic



(a) 60/40 Packet-Size Distribution

**Right Fig.** Additional delay imposed to the average system time of BE-traffic after applying a class-based WFQ policy. Comparison with an unregulated PQ policy for various percentages of resources exclusively allocated to LBE-traffic



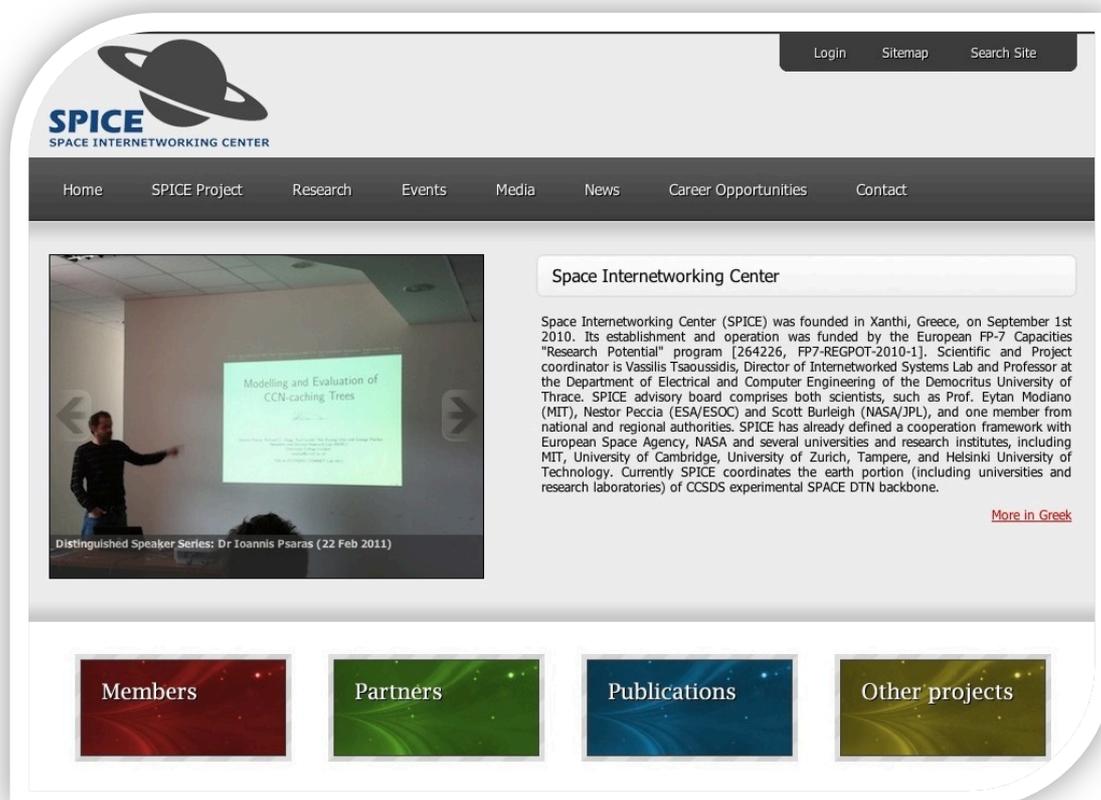
# SPICE Newsletter and Website

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

[www.spice-center.org](http://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



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 underprivileged 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. While both components are crucial for our access model, we intentionally delegated all computational tasks to the gateways, since we assume that DTN ferries have restricted energy and computational capabilities. Typically, the travel plan of buses, trams and trains is predefined and only minor delays can occur. Therefore, in our model we assume that all gateways have global knowledge of the connectivity plan. Of course, in case of a major delay, the updated traffic schedule is flooded into the network through a central administrative node.

DTN gateways are resource-capable fixed nodes located near ferry stops. We assume that certain gateways have access to the Internet through a

hotspot that exists in the area (*online DTN gateways*), while the majority is offline. All gateways have effectively enough buffer size to store messages from several end-users and are equipped with network interfaces for data exchange with the mobile devices of the end-users and the DTN ferries. Once an end-user device discovers a DTN gateway in its radius, a request to/from the Internet is transferred from/to the relevant application.

When a bundle is received by an offline gateway, valid paths between this gateway and online gateways are calculated based on the connectivity plan and a path that achieves earliest bundle delivery is selected. Once a path is selected, the gateway extracts the ID of the next gateway on this path, the ID of the ferry that will transfer the bundle and the estimated forwarding time

and stores the bundle in its buffer until a contact to the ferry becomes available, when it forwards the bundle.

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. Through extensive simulations, we show that CARPOOL successfully exploits existing knowledge on the connectivity plan of typical means of public transport, in order to identify a route from the source node to a WiFi access point, and performs significantly better than most well-known DTN routing protocols in terms of delivery ratio and overhead.

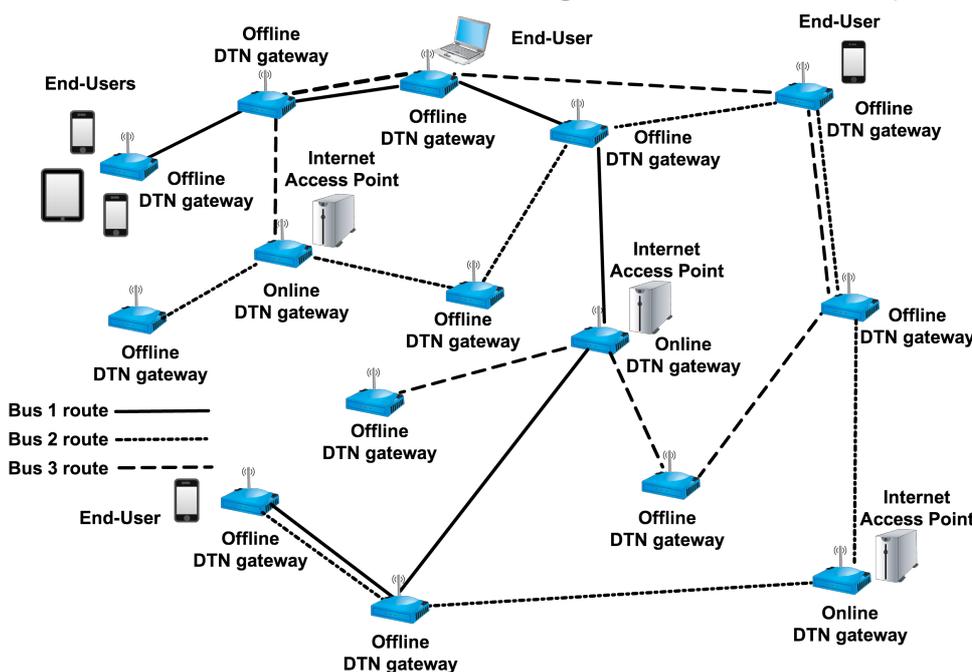


Fig. Sample topology

- S. Lenas, S. Dimitriou, T. Tsapeli and V. Tsaoussidis, "**Queue-Management Architecture for Delay Tolerant Networking**", WWIC 2011, Vilanova i la Geltrú, Barcelona, Spain, on June 15-17, 2011
- L. Mamatas, A. Papadopoulou and V. Tsaoussidis, "**Semi Markov modeling for User Mobility in Urban Areas**", 2<sup>nd</sup> 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.
- G. Drosatos, P. S. Efraimidis, I. N. Athanasiadis, E. D'Hondt and M. Stevens, "**A Privacy-Preserving Cloud Computing System for Creating Participatory Noise Maps.**", In proceedings of the 36th Annual IEEE Computer Software and Applications Conference (COMPSAC 2012), July 16-20, 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.
- D. Vardalis and V. Tsaoussidis, "**Energy-efficient Internetworking with DTN**", 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.
- G. Papastergiou, I. Alexiadis, S. Burleigh and V. Tsaoussidis, "**Delay Tolerant Payload Conditioning Protocol**", Elsevier Computer Networks, in press.
- 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**", 8<sup>th</sup> ACM MobiCom Workshop on Challenged Networks, CHANTS '13, Miami, Florida, USA, September 30, 2013.
- S.-A. Lenas, S. Burleigh, and V. Tsaoussidis, "**Bundle Streaming Service: Design, Implementation and Performance Evaluation**", Transactions on Emerging Telecommunications Technologies, November 20, 2013.
- A. Sathiaselan, D. Trossen, I. Komnios, J. Ott and J. Crowcroft, "**An Internet Architecture for the Challenged**", IAB Workshop on Internet Technology Adoption and Transition (ITAT), Cambridge, UK, December 4-6, 2013.

**Complete list of publications can be found at SPICE website.**



## Upcoming Events

***SPICE and the National Observatory of Athens organise  
"NETSPACE workshop on Networking Technologies for  
Efficient Space Data Dissemination and Exploitation" on  
February 18-19, 2014, in Athens, Greece***

***1<sup>st</sup> Global Access to the Internet for All (GAIA)  
IRTF group meeting in London, March, 2014***

***CCSDS Spring 2014 meeting series  
Noordwijkerhout, Netherlands  
March 31 - April 3, 2014***

***SPICE DTN Sensor Data Carrier project***

***SPICE Promotional Video***

***ESA's "Application of a BitTorrent-like Data Distribution  
Model to Mission" project mid-term review***

# Space Internetworking Center



## Newsletter Editor

■ Ioannis Komnios

## Newsletter Advisor

■ Prof. Vassilis Tsaoussidis

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Democritus University of Thrace

School of Engineering

Panepistimioupoli Xanthi

Kimmeria

Building A

67100

Xanthi, GREECE

Professor Vassilis Tsaoussidis

Telephone/Fax: 0030.25410.79.554

E-mail: [contact@spice-center.org](mailto:contact@spice-center.org)

[www.spice-center.org](http://www.spice-center.org)

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