Demonstration of Service-Differentiated Converged Optical Sub-Wavelength and LTE/WiFi Networks over GEANT

Bijan Rahimzadeh Rofoee[1], Kostas Katsalis[2], Yan Yan[1], Yi Shu[1], Thanasis Korakis[2], Leandros Tassiulasand[2], Anna Tzanakaki[1], Georgios Zervas[1], Dimitra Simeonidou[1]
(1) High Performance Networks Group, MVB, University of Bristol, UK. bijan.rofoee@bristol.ac.uk
(2) NITlab, Filikis Etairias 78Volos 38334 Greece

Abstract: A converged optical-wireless testbed is formed integrating TSON sub-wavelength networking in UK and the NITOS wireless solution in Greece. End-to-end service provisioning and flow differentiation are demonstrated across two networks communicating over the GEANT.
OCIS codes: (060.4250) Networks; (060.4510) Optical communications

1. Introduction

Mobile Cloud Computing (MCC) services [1] have emerged as a new computing paradigm that enable offloading resource intensive workloads from mobile devices to the cloud infrastructure, where datacenters with vast amounts of computational and storage resources support the deployed services. In the era of Internet of Things and Big Data, optical sub-wavelength switching solutions are among the next generation optical networking technologies that provide fine granular bandwidth, low latency and efficient optical transport and can greatly support the connectivity requirements of the MCC paradigm[1] (Fig. 1). In this work we use the Time-Shared-Optical-Network (TSON) to provide backhaul capabilities to a hybrid LTE/WiFi wireless network aiming at interconnecting fixed and mobile users with computational resources. We explain how TSON [2] can facilitate differentiated services across the converged infrastructure by prioritizing and differentiating traffic flows per time-slice. TSON takes advantage of enhanced functional blocks to address different quality of service (QoS) levels in the wireless backhaul domain in L2/L3 which also can be mapped to end users QoS requirements (Quality Class Indicator metrics in LTE and 802.11e in WiFi [3]). To demonstrate such an end-to-end flow transport with flow differentiation across domains we have implemented an international integrated test-bed comprising a TSON configuration in the UK and the hybrid LTE/WiFi wireless network NITOS [4] in Greece. We show how flows of different priorities go through TSON differentiation mechanism, and are segregated and matched in the NITOS backhaul for WiFi access points (APs) with different channel qualities. The experiment demonstrates the capabilities of such a converged platform in integrating DC, Optical, and wireless domains with QoS awareness.

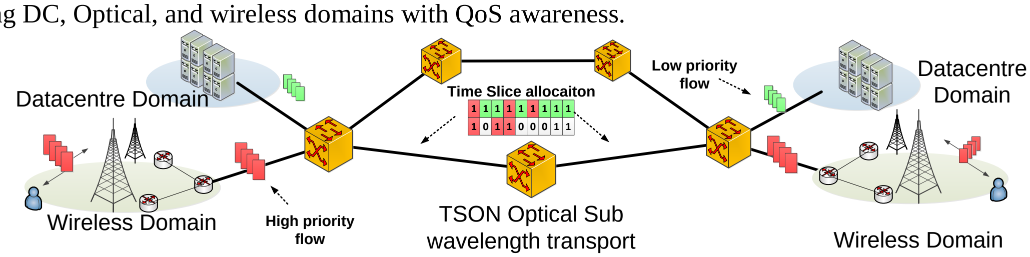

Fig. 1. Converged optical sub-wavelength and wireless networks to enables mobile and DC communications

2. Extended TSON service differentiation

TSON is a fast switched, synchronized, frame based optical sub-wavelength transport technology, which has been extended with programmable TDM functions [5] and can flexibly utilize a number of elements to differentiate between wide ranges of traffic flows. Figure 2 shows high-level TSON function blocks of the extended design which are used in this work to implement service differentiation. The extended programmable TDM functions allow changing the frame lengths on the fly, which essentially impacts the latency experienced by the services. The shorter the frame, the less delay imposed on the buffered traffic in the nodes. This means that to make the frame shorter, either the duration per time-slice (i.e. the bandwidth per time-slice) or the number of time-slices (bandwidth) should be compromised. The flexible TDM frame reprogramming makes a highly customizable system in QoS terms which can be tuned to match the requirements of other technology domains. The other element which impacts latency is the allocation pattern of time-slices over the TDM frames. In [6] we demonstrated how spreading the allocated time-slices across the frame rather than having them contiguously, located next to each other, improves latency as the buffered traffic is released more frequently. Another element which has been added to the TSON data path is priority queues. Traffic stored in higher queues is released faster than the lower queues. Apart from the on-chip factors, at the network level applying traffic engineering mechanisms and routing traffic towards paths with different costs can impact the quality of service experienced. In case of TSON with transparent optical fast switches the path length is the cost factor, which causes different travel times for the optical time-slices.

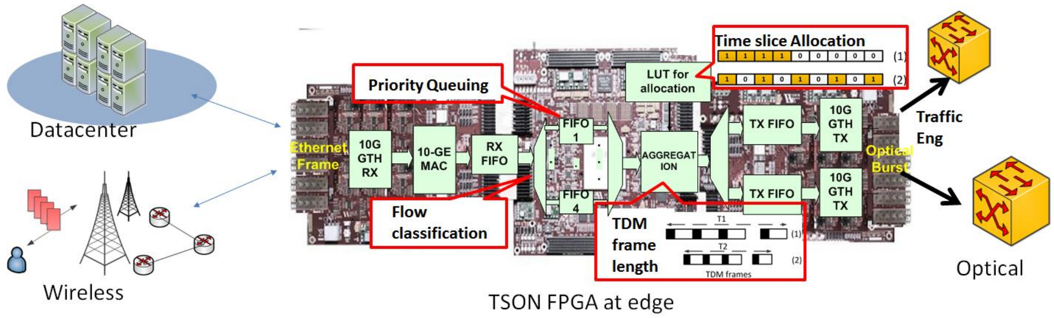

Fig. 2 TSON Extended FPGA function blocks for traffic/service differentiation across multiple domains

3. NITOS Wireless domain

NITOS [3] test-bed supports experimentation-based research in the area of wireless networks with facilities for LTE, WiFi, and WiMAX technologies. NITOS is an outdoor-deployed, non-RF-isolated test-bed with interference from devices operating in vicinity and the unlicensed bands and congestions, cause fluctuations in the capacities of the links and thus affect the properties of given 802.11 nodes. As the channel conditions greatly vary in time, in the wireless domain it is very difficult to provide exact throughput or delay guarantees to the end user. This makes conventional mapping of traffic to spectrum in the Access Point (AP) highly sensitive to channel conditions. In order to characterize the quality of the wireless link the throughput capabilities of the APs we used the Received Signal Strength Indicator (RSSI) and noise metrics. Based on the derived SNR values, we mapped the incoming traffic flows to APs with different channels conditions using OpenFlow based Ethernet switches in the mobile backhaul. This is done by setting the queueing structure and the throughput limits accordingly, based on the Level of Service defined for the flow in the TSON side.

4. Converged Optical-Wireless testbed and results

Figure 3 shows the topology of the converged optical-wireless testbed of the experiments. The optical testbed is based in Bristol, which uses three sub-wavelength switching TSON nodes (FPGA + PLZT fast switch) in a ring configuration, and fiber spools (3.5 and 8.1 km) are added on links to emulate transmission distances on different paths. The TSON network was programmed to use 32 time-slices, with different time-slice sizes (22.4 and 41.6 µs).

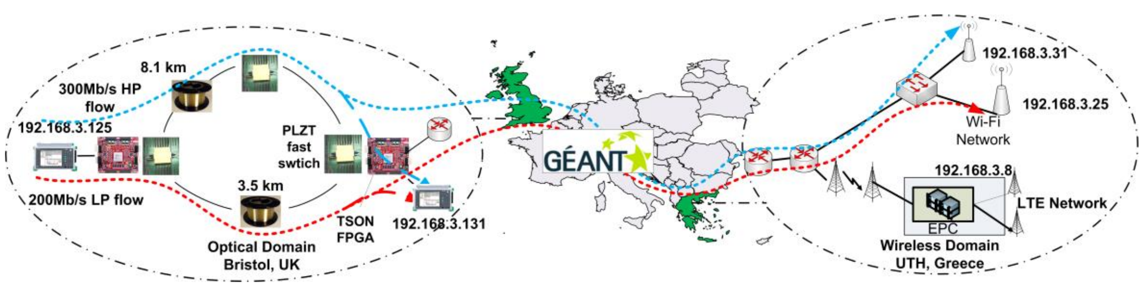

Fig. 3 Integrated TSON and NITOS testbed over GEANT Pan-European Research and Education Network.

A number of tests were carried out locally over each testbed to characterize and benchmark their performance. In the TSON testbed, two flows of 300Mb/s and 200Mb/s were transported using the appropriate number of time-slices depending on the time-slice bandwidth, to achieve error free transport. Traffic differentiation methods using exemplar allocation (1 means allocated) and frame durations as shown in profiles P1-P4 in Tab. 1. were applied to the flows. The profiles P1-P4 show combinations of frame lengths and allocation patterns which impact the latency.

Tab 1. Service differentiation profiles by applying combination of frame length and allocation patterns

	P1	P2	P3	P4
Frame length	~0.716 ms	~0.716 ms	~1.331ms	~1.331ms
Allocation	Non Contiguous(100100..)	Contiguous(11…000)	Non Contiguous(100100..)	Contiguous(11…000)

Figure 4 shows the results for 64 and 1500 Byte Ethernet sizes for FPGA-to-FPGA communications in TSON. It is observed that the shorter TSON TDM frame, using high priority queues, and with more distributed allocation of time-slices leads to faster traffic delivery. The tests were repeated over a more realistic scenario of having about 1.9 Gb/s background traffic to emulate bigger flows between Datacenters. In these tests links with different lengths of

3.5km and 8.1 km were used. The results in Figure 5 demonstrate how filling up the links with back ground traffic, in addition to the extended links in the TSON ring network impacted the latency figures As the networking conditions get more realistic, the effect of introducing priority queues has become more identifiable for profiles 1-4 with up to 10ms for high priority and 20ms for low priority flows.

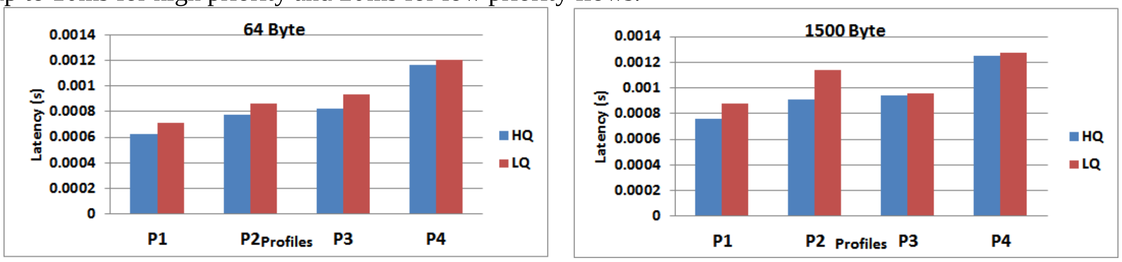

Fig. 4: TSON FPGA-to-FPGA tests for different profiles and priorities a) 64 Byte frames b)1500 bytes frames

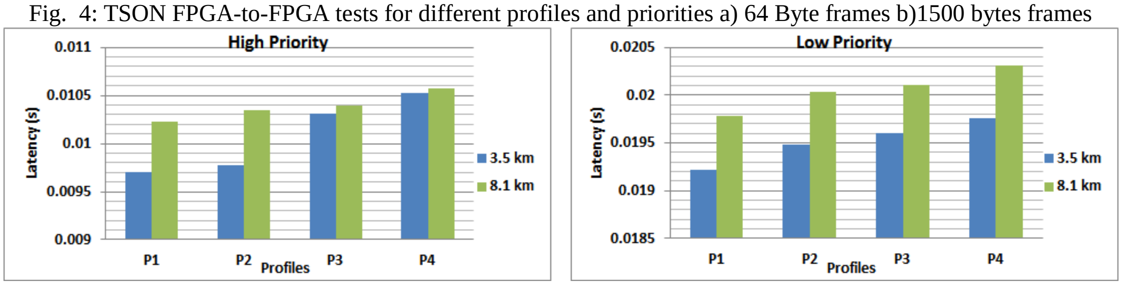

Fig. 5. TSON network tests for different profiles and lengths: a) high-priority queues b) low-priority queues

Two traffic flows of 300 Mbps high priority/P1 and 200Mb/s low-priority/P4 from TSON were transmitted to the NITOS wireless domain in Greece, where the traffic travelled through the National Research Networks and over the GEANT link. The performance over this link was quite volatile in terms of bandwidth and latency (as it carries real shared traffic for numerous services) affecting the end-to-end communications. Tab. 2 shows the available TCP and UDP end-to-end bandwidth along with the network results for UDP flows with high and low priorities.

Tab 2: bandwidth, latency, and jitter measurements between multiple points

	TCP BW(Mb/s)	UDP BW (Mb/s)	Latency (ms)	Jitter (ms)
TSON Bridge←→ UTH-Bridge	7.86D/7.85U	800 D/626U	64.2	0.072
TSON P1 High Priority←→ UTH-AP1:31	7.63D/7.74U	350D/350U	67.04	0.106
TSON P4 Low Priority ←→ UTH-AP2:25	7.61D/7.74U	250D/250U	67.2	0.172
TSON Bridge ←→ UTH-LTE	6.12/7.74U	102D/90U	72.86	0.18

In the wireless domain, and in the backhaul using OpenFlow switches the flows were directed to different access points. The WiFi spot (AP1) had RSSI of -45 dBm and noise of -90dBm from users and was set to receive high-priority flow, whilst AP2 with RSSI of -65dBm and -90dBm noise was the destination for the low priority flow. Table 2 shows the bandwidth; latency and jitter results measured end-to-end and for bidirectional transport. Traffic snapshots were taken to demonstrate the received bandwidth in different points in wireless backhaul shown in Fig 6.

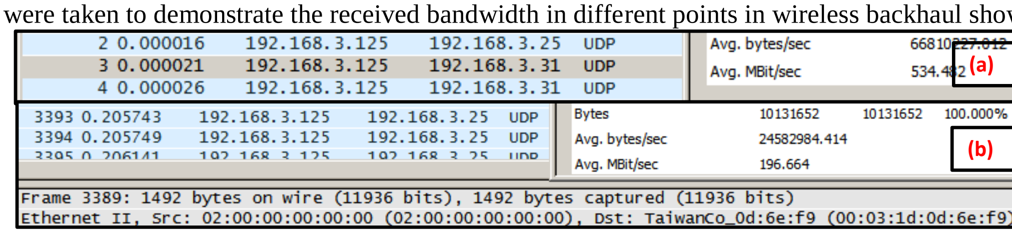

Fig. 6. (a) Wireshark capture at UTH bridge two flows (~500Mb/s), (b) capture at AP2 were 200 Mb/s low priority traffic.

Conclusion: In this work we demonstrated integration of advanced sub-wavelength optical and wireless technologies to provide a converged testbed for end-to-end service provisioning and differentiation. Real time traffic was sent across the two testbeds of TSON in the UK, and NITOS wireless in Greece over a GEANT link. Different TSON traffic profiles were mapped to wireless access points with different channel qualities.

Acknowledgments: This work is supported by EU funded CONTENT and UK EPSRC TOUCAN projects.

4. References

[1] Tzanakaki, et al, "Virtualization of heterogeneous wireless-optical network and IT infrastructures in support of cloud and mobile cloud

[2] Yan, et al, 'High performance and flexible FPGA-based time shared optical network (TSON) metro node'. J.OpEx13, v21. 2013

[3] ixia "Quality of Service (QoS) and Policy Management in Mobile Data Networks",2013

[4] http://nitlab.inf.uth.gr/NITlab/

[5] Yan, et al, 'FPGA-based optical network function programmable node.' OFC, pp.1,3, 9-13 March 2014

[6] Rofoee BR, et al, Programmable on-chip and off-chip network architecture on demand for flexible optical intra-datacenters, J.OpEx.13, v21