SEVENTH FRAMEWORK PROGRAMME

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Abstract:

This document is the first deliverable of the WP23 "Topical Project on Optical Communication Networks in Support of user mobility and Networks in Motions". This report contains the participant's expertise, and also planned activities into the BONE project. There are 12 active partners interested and involved in this work package and 6 joint activities are proposed. Moreover, 3 potential mobility actions are planned during the first year of this topical project.

Keyword list:

Joint Activities, planned activities, inventory of expertise

Disclaimer

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Executive Summary:

This document is the first deliverable of the work package “Typical Project on Optical Communication Networks in Support of user mobility and Networks in Motions”. The main objectives of this deliverable are to provide and compile the partner expertise and also the planned joint activities so far in the framework of BONE project. According to the Annex I (Description of Work) of BONE project, there are **12** active partners (AIT, Ericsson, IBBT, ISCOM, IT, TUE, UAM, UCAM, UCL, UDE, UH, and UPVLC) interested and involved in this work package. Other partners in this topical project (COM, FRUNHOFER, ICCS/NTUA, POLITO, TELENOR, TUB, and UEssex) did not declare their interest for participation in the first year activity planning. Based on common research topics **6** joint activities are proposed and planned so far. The topics covered and planned by this work package try to address hardware implication issues for networks in motion, state of the art definition for components supporting Free-Space Optics (FSO) networks in motions, converged MAC algorithms for unified optical wireless functionality, Ultera Wideband (UWB) radio-over fiber transmission in indoor environments using different media, optimizaing service delivery in a converged hybrid optical-wireless network and all-optical routing architecture of radio signals using label processing techniques for in-building optical networks.

1. Introduction

Playing the role of a Network of Excellence, BONE project has brought together over several years of research activities in Europe in the field of Optical Networks and it intends to repeat and validate this effort by stimulating a more intensified collaboration, exchange of researchers and building on its centralized activities, Topical Projects (TP), and Virtual Centres of Excellence (VCE) that can serve to European industry with education and training, research tools and test-beds and eventually pave the way toward new technologies and architectures.

This work package, identified as a TP on ***Optical Communication Networks in Support of user mobility and Networks in Motions***, combines a large number of partners currently working on various research fields interoperable to each other.

1.1 TP Objectives

Within the next few years, networks in motion will play a central role in the people's lives, worldwide. An upcoming networking concept is emerging based mainly on the requirements of mobile working groups of people of various societal sectors that demand ubiquitous connectivity. The individual subscribers themselves will increasingly carry around their own short-range personal network which is constituted when networked personal devices interconnect and create a Personal Area Network (PAN).

Many groups of users exist who follow a slowly or a fast mobility pattern and therefore access on mobile vehicles (car, train, airplane) or just to people moving on foot becomes a necessity. The moving networks often need to communicate with each other or the outside world, resulting in a unique new form of network namely the "*network in motion*". Thus the surrounding infrastructure needs to be able to support a large amount of personal network connections. For such new application scenarios, it is critical that the next generation of networks employs intelligent components and devices that in a way sense the user needs and are able to provide guaranteed content delivery in an efficient and secure manner (while providing the privacy of the communication).

For such a system to run successfully, intensive research must be done. Particularly, the use of optical network solutions in the aggregation and core part of the network is essential and requires extensive research in the both the networking and technology areas.

The planned effort in this work package will be divided in three main activities according to the identified objectives, which will run in parallel for the duration of the project. The first activity is ***technology oriented*** and will focus on the investigation and development of novel approaches able to support networks of wireless users that require rapid handover characteristics and high bandwidth connectivity. The second activity focuses on the ***aggregation network*** that supports the wireless users and specifically on switching solutions with rapid reconfiguration characteristics. The third activity is ***network and control layer*** oriented and will study new MAC, routing and signalling protocols to support the characteristics of networks in motion.

The three activities cover research areas that can be initially developed independently but under the same general focus as this will be defined by the properties of networks in motion. Therefore, first, it is important to define a common knowledge platform about the possible solutions and the properties of these novel network approaches that support seamless

connectivity of various wireless users in a rapidly reconfigurable environment. The purpose of this knowledge platform will be:

- *To provide the basic requirements and characteristics that novel technology and networking solutions should target in.*
- *To identify the limitations and challenges that require a possible solution and consequently push technology and networking towards these directions.*

Finally it is of interest in this work package to join together efforts that could possibly evaluate or even demonstrate complete solutions in support of the objectives.

More specifically this topical project is focusing on providing collaborative research towards three main directions identified in the following objectives:

- *To perform studies on intelligent technologies and design challenges for wireless access in networks in motion (e.g. based on radio over fiber (RoF), free-space optics (FSO), or conventional wireless solutions with optical fibre feed)*
- *To perform studies on networking properties and switching characteristics for the aggregation and core networks in support of networks in motion (e.g. Switched Ethernet based solutions or advance schemes like OBS/OPS),*
- *Development of control plane and signalling algorithms and protocols for networks in motion (e.g. MAC layer design or network layer approaches with QoS quarantines, resource reservation approaches etc.*

1.2 Deliverable goals

This deliverable aims at integrating the partners' research activities and expertise on the topic of *Optical Communication Networks in Support of user mobility and Networks in Motions* and provide a targeted common effort with the following outcomes: **a)** The development of a knowledge platform on Optical Communication Networks in Support of user mobility and Networks in Motions and **b)** The promotion of novel ideas for the convergence of optical and wireless networks for provisioning of user mobility.

In order to materialize the objective of this TP, it is essential to compile an inventory of expertise and then based on the common interests of individual participating partners; joint activities will be planned and executed during the running period of this work package. This deliverable presents the inventory of collected expertise of each *interested* and *involved* partner in this TP. Furthermore based on the common interests of participants, the proposed joint activities are also covered in the 3rd section of this deliverable. Final comments and conclusions are presented at the end of this deliverable.

2. Participants

This section covers the collected expertise of the interested partners and participants in this TP (WP26). The partners and their expertises are presented according to the alphabetical order of their designated short name (or abbreviation). According to the Annex I (Description of Work), there are (16) partners in total, which are collaborating in this work package. However there are also some additional interested partners, who will collaborate in joint research activates. Table 1 (in alphabetic order of partners short name) provides a list of participant and the code of joint activity(ies), in which they are involved. A detailed description of these joint activities is provided in the next chapter.

Table 1: Participant and their interested joint activity code (see Table 3)

Partner Number	Short Name	PM Allocation	Joint Activity Code
P19	AIT	3.5	2, 3, 4, 5, 6
P08	COM	0.5	-
P49	Ericsson	0.5	1
P04	FRUNHOFER	1.5	-
P01	IBBT	0.5	-
P20	ICCS/NTUA	1.0	-
P28	ISCOM	0.5	2
P37	IT	0.5	2
P30	POLITO	0.5	-
P35	TELENOR	1.0	-
P05	TUB	0.5	-
P36	TUE	0.5	5,6
P11	*UAM*	-	5,6
P45	UCAM	1.5	-
P46	*UCL*	-	3
P06	UDE	1.00	1
P47	UEssex	0.75	-
Affiliate Partner	*UH*	-	3
P15	UPVLC	0.5	4

In the following section an inventory of partner expertise is complied.

2.1 Research and Educational Laboratory in Information Technologies - AIT

Partner organization name: Research and Educational Laboratory in Information Technologies

Short name: AIT

Areas of expertise:

AIT is a centre of excellence in ICT research and graduate education. The main role of AIT as a research and educational institute is to provide high quality research in the field of telecoms and IT, as well as training through three post-graduate educational programs and special professional courses focused on the industrial needs. AIT participates in BONE project with its 'Networks and Optical Communications' (NOC) research group. The group maintains a broad range of research activities and technical expertise supported be a state-of-the-art laboratory to that provides innovative research activities on optical communications. The work carried out within the AIT's NOC group is focused on optical network infrastructures for existing and future broadband networks and services in access, metro and wide area networks. Specific areas of interest include novel architectures for circuit-, burst- and packet- switching, optical system and subsystem design, signalling and routing protocols, network resilience, service aware network design and traffic engineering, advanced transmissions and switching techniques, and techno-economic studies.

The expertise of AIT's NOC group in the field of transparent networks and impairment constraint based routing studies is proven through a number of journal publications as well as invited talks in major international conferences in optical communications. Moreover relative activities in the general field of optical networking studies, design and evaluation are carried out through a number of EU projects where AIT is actively participating, like the DICONET project on Dynamic Impairment Constraint Networking for Transparent Mesh Optical Networks, SARDANA, APACHE, and EUROFOS.

Relevant Publications:

[1] Tomkos, I., et al., "Impairment constraint routing in mesh optical networks", (Invited paper), OFC 2007, Anaheim, USA.

[2] G. Markidis, et al., "Impairment Constraint Based routing in Optical Networks Employing 2R Regeneration", ECOC 2006, Cannes, France, September 2006

[3] Tomkos, I., et al., "Benefits from the Use of Impairment Constraint Routing in Optical Networks", International Journal "Annals de Telecommunications", Special issue on "Simulation techniques for optical networks", 2006

[4] Tomkos, I., et al., "Q-factor based Constraint Routing in Optical Networks", SPIE Newsletter, 2006

[5] G. Markidis, et al., "CoS assignment based on physical performance parameters in OBS networks", 8th International Conference on Transparent Optical Networks (ICTON 2006) conference, June 18-22, 2006, Nottingham, United Kingdom.

[6] Tomkos, "Impairment constraint routing in transparent and managed reach optical networks", (Invited paper), APOC 2005.
[7] P. Kalkani, et al., "Benefits of Q-factor based routing in optical networks", ECOC 2005.
[8] C. Mas, et al., "A failure location algorithm for transparent optical networks", IEEE Journal on Selected Areas in Communications, August 2005.
[9] C. Mas, et al., "Comparison of transparent versus opaque interconnecting nodes of OADM rings with respect to failure location", ICTON 2005
[10] Tomkos, I., et al., "Performance Engineering of Metropolitan Area Optical Networks through Impairment Constraint Routing", IEEE Communications Magazine, vol. 42, no. 8, pp. S40 - S47, Aug. 2004.
[11] C. Mas, et al., "Optimal Monitoring Equipment Placement for Fault and Attack Location in Transparent Optical Networks" IFIP Networking 2004.
[12] C. Mas, et al., "Optimal Monitoring Equipment Placement for Fault and Attack Location in Transparent Optical Networks", Lecture Notes in Computer Science, 2004.
[13] C. Mas, et al., "Failure management in optical networks", Invited talk, IEEE ICTON'03, July 2003.
[14] C. Mas, et al., "A framework for failure prevention and management in all-optical networks", ITCOM'03, September 2003, Orlando, USA.

2.2 Ericsson

Partner organization name: Ericsson

Short name: Ericsson

Areas of expertise:

The main research activity will focus on the investigation and development of novel approaches able to support the hardware for networks of wireless users that require rapid handover characteristics and high bandwidth connectivity. Reliability of components in such networks and sensor applications will be researched as part of this work package. Switching technologies will be reviewed that supports the optical communication networks in support of user mobility and networks in motion.

2.3 Interdisciplinair Instituut voor Breedbandtechnologie vzw.- IBBT

Partner organization name: Interdisciplinair Instituut voor Breedbandtechnologie vzw.

Short name: IBBT

Areas of expertise:

The IBCN research group of IBBT-Ghent University has investigated in detail the broadband delivery on trains (see references below). To provide a high quality broadband connection for train passengers, a solution was proposed based on RF antennas on regular distances along the rail track, which are interconnected and internet-connected via an optical ring network. In this optical network, Radio-over-Fiber technology is proposed to reach a cost-efficient solution. Based on a Moveable Cell Concept, the negative influence of frequent handovers can be minimal.

Relevant Publications (OPTIONAL):

[1] F. De Greve, B. Lannoo, L. Peters, T. Van Leeuwen, F. Van Quickenborne, D. Colle, F. De Turck, I. Moerman, M. Pickavet, B. Dhoedt, P. Demeester, "FAMOUS : A network architecture for delivering multimedia services to Fast Moving Users", Wireless Personal Communications Journal, ISSN 0929-6212, vol. 33, pp. 281-304, Jun. 2005.

[2] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Radio-over-Fiber Based Solution to Provide Broadband Internet Access to Train Passengers", IEEE Communications Magazine, ISSN 0163-6804, vol. 45, no. 2, pp. 56-62, Feb. 2007.

[3] B. Lannoo, J. Van Ooteghem, D. Pareit, T. Van Leeuwen, D. Colle, I. Moerman, P. Demeester, "Business Model for Broadband Internet on the Train", The Journal of The Institute of Telecommunications Professionals (ITP, formerly TCN), ISSN 1477-4739, vol. 1, no. 1, pp. 19-27, Jul.–Sep. 2007.

[4] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Radio over Fiber technique for Multimedia Train Environment", Proc. of NOC 2003, 8th European Conf. on Networks and Optical Communications, pp. 99-106, Vienna, Austria, 1-4 Jul. 2003.

[5] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Optical Switching Architecture to Realize 'Moveable Cells' in a Radio-over-Fiber Network", Proc. of ICTON/GOWN 2004, 6th International Conf. on Transparent Optical Networks, vol. 2, pp. 2-7, Wroclaw, Poland, 4-8 Jul. 2004 (invited).

[6] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Optical Switching Architecture to Implement Moveable Cells in a Multimedia Train Environment", Proc. of ECOC 2004, 30th European Conf. on Optical Communication, vol. 3, pp. 344-345, Stockholm, Sweden, 5-9 Sep. 2004.

[7] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Extension of the Optical Switching Architecture to Implement the Moveable Cell Concept", Proc. of ECOC 2005, 31st European Conf. on Optical Communication, vol. 4, pp. 807-808, Glasgow, Scotland, 25-29 Sep. 2005.

[8] B. Lannoo, D. Colle, M. Pickavet, P. Demeester, "Comparison of two Optical Switching Architectures to Provide a Broadband Connection to Train Passengers," Proc. of OFC 2006, Anaheim, US, 5-10 Mar. 2006.

[9] B. Lannoo, J. Van Ooteghem, D. Pareit, T. Van Leeuwen, D. Colle, I. Moerman, P. Demeester "Business Model for Broadband Internet on the Train", Proc. of FITCE 2007, 46th Federation of Telecommunications Engineers of the European Community Congress, pp. 60-66, Warsaw, Poland, 30 Aug.-1 Sep. 2007.

2.4 Superior Institute of Communications and Information Technologies - ISCOM

Partner organization name: Superior Institute of Communications and Information Technologies

Short name: ISCOM

Areas of expertise:

Please identify in a few paragraphs your key research areas and proposed approaches for "Optical communication networks in support of user mobility and networks in motion", within the framework of BONE-WP23.

The key research topics at ISCOM, Ministry of Economic Development Communication Department, in the area of WP23 FP7 NoE BONe are focused to the optical wireless communications. In particular several experiments have been carried out on broadband, both single and multi channel, free space optical transmissions. Particular interests are devoted to the applications of this technology to "in motion networks" where several challenges are faced like: auto tracking, fast connections/re routing, chaotic movements & fast re alignments, et alt. Experimental joint activities are planned to be performed with IT and AIT partners.

Relevant Publications:

[1] D.M.Forin ,G.M.Tosi Beleffi ,N. Corsi, V. De Sanctis,V. Sacchieri ,G. Cincotti ,F. Curti , A.Teixeira, *"Very high bit rates WDM transmission on a Transparent FSO System",* **IEEE Leos ECOC 2007 P131 sept 2007.**

[2] V. Sacchieri, V. De Sanctis, N. Corsi, F. Curti, M. Guglielmucci, G. Tosi Beleffi, D. Forin, G. Cincotti, *"DWDM transparent FSO system for in/outdoor applications at high bit rates",* **IEEE ICTON 2007, Conference, July 2007.**

[3] Hideaki Kotake*, Shinichiro Haruyama*, Masao Nakagawa*, Kiyotaka Seki** BER "Characteristic of Ground-to-Train Communication SystemUsing Free-Space Optics Technology" **ICTON 2007 165 Tu.D3.5.**

[4] J. Grubor, O.C. Gaete Jamett, J.W. Walewski, S. Randel, K.-D. Langer: High-speed wireless indoor communication via visible light, *in* **ITG Fachbericht 198, pp. 203-208, Berlin und Offenbach: VDE-Verlag, 2007**

2.5 Instituto de Telecomunicações - IT

Partner organization name: Instituto de Telecomunicações

Short name: IT

Areas of expertise:

Insituto de Telecomunicações has expertise in several fields related to the WP23, to name a few:

- Radio over fibre technologies and related issues
- Free space optics technologies and related issues
- Optical switching technologies

Relevant Publications:

[1] A. Brízido, M. Lima, A. Teixeira, M. Larrode, T. Koonen, "UMTS radio over fiber link performance analysis based on low cost uncooled laser", Microwave and Optical Technology Letters, 51 (1): 6-9, Jan 2009.

[2] Almeida, C; Teixeira, A; Lima, M, "Performance analysis of multi-format multi-wavelength Radio over Fiber systems based on low cost optical components", ICTON Jun 2008.

[3] Forin, DM; Tosi Beleffi, GM; Curti, F; Corsi, N; De Sanctis, V; Sacchieri, V; Teixeira, ALJ; Cincotti, G,"On field test of a wavelength Division Multiplexing Free Space Optics transmission at very high bit rates", ConTel June 2007

2.6 Technische Universiteit Eindhoven - TUE

Partner organization name: Technische Universiteit Eindhoven

Short name: TUE

Areas of expertise:

TUE is a research-driven and design-oriented technical university, which mainly aims to educate young people at an academic level in the domain 'engineering science and technology'. Within the department of Electrical Engineering, research and education is done in the areas of telecommunication, signal processing, and energy transfer. The inter-faculty institute COBRA – Communication technology: Basic Research and Applications – performs research in the area of broadband telecommunication techniques, encompassing optical communication as well as radio communication. The Electro-Optical Communication Systems (ECO) group focuses its research on optical communication system techniques, ranging from very high speed long range transmission links, ultra-fast (all-)optical packet switching nodes, to multi-service flexible access, radio-over-fibre and in-building networks.

TUE plans to contribute to the BONE WP23 on reconfigurable network architectures featuring dynamically routed wireless access, regarding specifications and architecture design, and multi-standard wireless network provisioning. TUE has extensive laboratory facilities such that any concept may be validated via system experiments.

Relevant Publications:

[1] A.M.J. Koonen and M. García Larrodé, "Radio over MMF techniques – Part II: Microwave to millimeter-wave systems", *IEEE/OSA J. Lightwave Technol*, vol. 26, no. 15, pp. 2396-2408, August 2008 (invited).

[2] M. García Larrodé and A.M.J. Koonen, "All-fiber full-duplex multimode wavelength-division-multiplexing network for radio-over-multimode-fiber distribution of broadband wireless services", *IEEE Transactions on Microwave Theory and Techniques,* vol. 56, no. 1, pp. 248-255, January 2008.

[3] T. Spuesens, B. Huiszoon, E. Tangdiongga, and A.M.J. Koonen, "Versatile broadband service delivery on PON employing a hybrid optical code division multiple access/radio-over-fiber system", in *Proc. European Conference on Optical Communications (ECOC) 2008*, paper P.6.23, September 2008, Brussels, Belgium.

[4] B. Huiszoon, F.T.H. den Hartog, M. García Larrodé, and A.M.J. Koonen, "Layer 2 and 3 contention resolution and radio-over-fiber in OCDMA PON for transparent optical access in personal networks", *IEEE/OSA Journal of Lightwave Technology*, vol. 26, no. 13, pp. 1752-1764, July 2008.

[5] B. Huiszoon, G.D. Khoe, and A.M.J. Koonen, "Fiber-to-the-PAN: towards optical in personal networks", in *Proc. Annual Symposium of the IEEE/LEOS Benelux Chapter 2004*, pp. 5-8, December 2004, Ghent, Belgium.

2.7 Universidad Autónoma de Madrid - UAM

Partner organization name: Universidad Autónoma de Madrid

Short name: UAM

Areas of expertise:

The Universidad Autónoma de Madrid (UAM) is the third largest university in central Spain. The Networking Research Group (NRG) at the UAM is involved in BONE through participation in WP11 which is a Virtual Centre of Excellence on "Network Technologies and Engineering" and through leadership of WP24 which is a Topical Project on "Edge-to-Core Adaptation for Hybrid Networks". The NRG group is actively pursuing research in computer communication networks, with a focus in the main areas: *high bandwidth networks*, *traffic characterization*, *optical networks: optical burst switching and optical access networks, network dimensioning*, and *management and monitoring of communication networks*.

Recently, the group has become interested to participate in WP23, and in particular by contributing in the areas of network reconfigurability, dynamic network management, and real-time traffic monitoring and characterization.

Relevant Publications:

[1] J.L. García-Dorado, J.A. Hernández, J. Aracil, J.E. López de Vergara, F. Montserrat, E. Robles and T. de Miguel, "On the duration and spatial characteristics of Internet traffic measurement experiments", *IEEE Communications Magazine*, vol. 46, no. 11, pp. 148-155, November 2008.

[2] V. López, C. Cárdenas, J. A. Hernández, J. Aracil and M. Gagnaire, "Extension of the Flow-Aware Networking (FAN) architecture to the IP over WDM environment," *IEEE International Telecommunication NEtworking WorkShop on QoS in Multiservice IP Networks (IT-NEWS/QoS-IP 2008)*, February 2008.

2.8 University of Cambridge - UCAM

Partner organization name: University of Cambridge

Short name: UCAM

Areas of expertise:

UCAM has been working in the field of Radio over Fibre transmission since 2001 where it carried out the national FRIDAY project with UCL. This was successful in developing low cost radio over fibre systems using datacom (i.e. un-cooled, uncontrolled) grade lasers, both FP and VCSEL, operating with ultra-high linearity. The key development was the discovery of robust methods to allow transmission of radio channels over installed base MMF at carrier frequencies well beyond the fibre bandwidth (up to a world leading 20GHz to date). This allowed the development of 3G and WLAN Distributed Antenna System (DAS) networks, which are now being commercialised via Zinwave Ltd.

Subsequently we have worked on wideband RoF networks – those which are agnostic as to what services are transmitted over them. We have shown that, if the RoF system is sufficiently linear, it is possible to transmit simultaneously multiple services (e.g. 2G, 3G, Wifi, TETRA etc) over the same link. Issues that have needed to be solved are the linearity of the link over such a wide bandwidth, the performance of MMF optical channel which can exhibit strong fading behaviour if not properly designed and the isolation of the antennas which can lead to the system being limited by feedback of the downlink signal into the uplink.

We have also been recently working, within the UK national project TINA, on combining RFID signals with communications systems over the same RoF DAS system. Given that conventional communications services all have similar downlink power levels for in-building environments, RFID provides a significant challenge as the downlink powers can be 15-20dB more than for the communications services. Using feed forward linearization techniques we have been able to operate the RoF DAS with sufficient dynamic range for all services, thus allowing a location sensing capability to the communications DAS.

Finally we have also worked on SOA based amplification and switching networks for RoF signals. Here we can switch on sub-frame timescales and can construct switch networks scalable to 64x64 port count and above.

Relevant Publications:

[1] "Uplink and downlink coverage improvement of 802.11g signals using a distributed antenna network", M J Crisp, S Li, A Watts, R V Penty and I H White, IEEE Journal of Lightwave Technology, Vol 25, pp 3388-3395, 2007

[2] "High dynamic range linear analog data links (1-20 GHz) using room temperature DFB laser diodes", P Hartmann, J D Ingham, M Webster, D Wake, A Wonfor, R V Penty, I H White, A J Seeds and J K White, SPIE Annual Meeting, San Diego, 2003 (invited)

[3] "Broadband multimode fibre based IEEE 802.11 a/b/g WLAN distribution system", P Hartmann, X Qian, R V Penty and I H White, International Topical Meeting on Microwave Photonics, Maine, 2004

[4] "A novel scalable photonic analog switch architecture based on semiconductor optical amplifiers", X Qian, P Hartmann, R V Penty, I H White and W P Krug, Avionics Fiber Optics and Photonics Conference, Minneapolis, 2005 (invited)

2.9 University College London - UCL

Partner organization name: University College London

Short name: UCL

Areas of expertise:

UCL has a wide range of expertise in Radio-over-fibre systems and networks. It has working on the UK national project FRIDAY (with UCAM) to develop low-cost radio over multi-mode fibre systems which have been commercialised via Zinwave Ltd. It has also participated in the EU projects Gandalf and IPHOBAC as well as the Networks of Excellence in the area of microwave photonics Nefertiti and ISIS.

Although the groups involved in this activity have in the past mainly worked on the physical layer, more recent work has also focused on networking issues in radio over fibre networks. This has included considerations of how systems may be integrated into Passive Optical Networks [1] and considerations of the interaction of the radio MAC with optical fibre networks [2].

Funding has recently been secured to enable the development of a converged laboratory o enable the testing of MAC protocols over realistic physical layers and over data carrying optical networks.

Relevant Publications:

[1] "Optical network architectures for dynamic reconfiguration of full duplex, multiwavelength, radio over fiber," J. C. Attard and J. E. Mitchell, *OSA Journal of Optical Networking. **5**, 435-444 (2006)*

[2] Performance Impairments in Single-Mode Radio-Over-Fiber Systems Due to MAC Constraints, Kalantari-Sabet, B.; Mjeku, M.; Gomes, N.J.; Mitchell, J.E.;" Journal of Lightwave Technology, Volume 26, Issue 15, Aug.1, 2008 Page(s):2540 - 2548

[3] "Transmission of 37.6-GHz QPSK Wireless Data Over 12.8-km Fiber With Remote Millimeter-Wave Local Oscillator Delivery Using a Bi-Directional SOA in a Full-Duplex System With 2.2-km CWDM Fiber Ring Architecture" T. Ismail, C-P. Liu, J.E. Mitchell, A.J. Seeds, X. Qian, A. Wonfor, R.V. Penty, I.H. White *IEEE Photonics Technology Letters, Vol 17(9) Sept 2005 pp.1989- 1991*

[4] TCP and UDP Performance over Fibre-fed IEEE 802.11b Networks" M. Mjeku, B. Kalantari Sabet, J.E. Mitchell, N.J. Gomes, *12th Microcoll Colloquium on Microwave Communications, Budapest, Hungary, May 2007, pp. 89-92*

[5] "Performance of TCP transmission over IEEE 802.11b network with long fibre distribution links" B. Kalantari Sabet, M. Mjeku, N. J. Gomes, J. E. Mitchell, *ISIS-IPHOBAC Workshop and Summer School, Budapest, Hungary, May 2007*

[6] MAC Constraints on the Distribution of 802.11 using Optical Fibre" B. Kalantari-Sabet and J.E. Mitchell, *in Proc European Conference on Wireless Technology, Manchester September 2006 paper ECWTPoster-2*

[7] "Full-Duplex Wireless-over-fibre Transmission Incorporating a CWDM Ring Architecture with Remote Millimetre Wave LO Delivery Using a Bi-Directional SOA" T.Ismail. C-P Liu, J.E. Mitchell, A.J. Seeds, X. Qian, A. Wonfor, R. V. Penty, I.H. White. *in proc the 2005 Optical Fiber Communications Conference (OFC), paper OThG7.*

2.10 Universität Duisburg-Essen - UDE

Partner organization name: Universität Duisburg-Essen

Short name: UDE

Areas of expertise:

- Design and characterisation of broadband fibre (glass and polymer) and wireless (GHz) links, including particularly radio-over-fiber (RoF) [1-3]

- Rf over MMF/POF for Fixed-Wireless communications [3, 4]

- In-building fiber automation & control systems combined with sensor applications

- Cooperation with the research laboratories of the In-Haus I and II of FhG-IMS, Duisburg in the framework of intelligent homes, e.g. for health care, small offices, etc.

- Cooperation with ETH Zurich for low power WLAN MMF/POF Interface using Vertical Electroabsorption Transceivers (VEAT) [4]

Laboratory facilities:

-RoF 60GHz Access Demonstrator

-Clean room facilities for III-V component research and production, MOVPE, MBE, material analysis

-Experimental facilities in short range in-the-field access with a 200m Plastic Optical Fiber and (POF) 100 m Multimode Silica fiber Testbed

Test and Measurement Equipment:

- BER Test Set 12.5 GS/s

- mm-wave up to 110GHz

- Tunable Laser sources, Laser measurement equipment, TDM, WDM

Relevant Publications:

[3] M. Weiß, M. Huchard, A. Stöhr, B. Charbonnier, S. Fedderwitz, D. Jäger, 60GHz Photonic Millimeter-Wave Link for Short to Medium-Range Wireless Transmission up to 12.5Gb/s, Special Issue of the IEEE Trans. Microw. Theory Tech. and J. Lightw. Techn., pp. 2424-2429, 2008, (invited)

[4] I. Möllers, R. Gaudino, A. Nocivelli, H. Kragl, O. Ziemann, N. Weber, T. Koonen, C. Lezzi, A. Bluschke, S. Randel, D. Jäger, "Plastic Optical Fiber Technology for Reliable Home Networking – Overview and Results of the EU Project POF-ALL", submitted to IEEE Comm. Mag., May 2008

[5] R. Gaudino, D. Cardenas, P. Guignard, S. Meyer, I. Möllers, M. Bellec, B. Charbonnier, N. Evanno, A. Pizzinat, D. Jäger, "Future Internet in Home Networks: Towards Optical Solutions?", to be published at Future Internet Conference and Technical Workshops, Prague, May 2009

[6] Ingo Möllers, Mike Bülters, Amanuel Geda, Dieter Jäger, „Radio-over-Fiber Communication Using a Vertically Integrated Transceiver", IEEE International Mini-Symposium on Electromagnetics and Network Theory and their Microwave Technology Applications (EMNT), Munich, Germany, October 8-9, 2008

2.11 University of Hertfordshire - UH

Partner organization name: University of Hertfordshire

Short name: UH

Areas of expertise:

The group's research has been focusing on the development of novel protocol suites to implement very high capacity access networks and their enhancement to support long-reach, wide-splitting integration of mobile end-users. To that direction converged access topologies, allowing for the transparent transmission of wireless network solutions over legacy and long-reach PONs with extended wavelength band overlay are in the focus.

QoS by means of service differentiation, service level agreement and buffer queuing status for individual users across the PON platform should be demonstrated by means of dynamic bandwidth and wavelength allocation algorithms in a new MAC suite that would allow centralised management of ONU requirements on demand in addition to extended time frames associated with resource assignment and packet propagation.

To the clear cost saving in hardware, the topology would benefit from a flat control plane and seamless convergence where signaling and control messages are directly exchanged between the OLT and mobile users. On-demand bandwidth provisioning to enhance wireless capacity can be provided by dynamically dropping additional wireless channels (WiMAX, WiFi, LTE) to congested ONU/Base-Stations, centrally by the OLT. This would provide advanced networking in the form of resilience since the overlapping cells allow channels from neighboring ONU/BSs to access users in the coverage area of a failing BS as well as increasing the capacity of the wireless network.

Relevant Publications (OPTIONAL):

[1] Y. Shachaf, C.-H. Chang, P. Kourtessis, J. M. Senior, "Multi-PON access network using a coarse AWG for smooth migration from TDM to WDM PON," *OPTICS EXPRESS*, Optical Society of America (OSA), vol. 15, pp. 7840-7844, June 2007

[2] C. Hung, P. Kourtessis, J. M. Senior "Dynamic Bandwidth assignment for Multi-service access in long-reach GPON", *33rd European Conference and Exhibition on Optical Communication* (ECOC2007), paper 8.4.3, pp. 277-278, Sept. 2007, Berlin

[3] A. Gliwan, C. H-. Chang, Y. Shachaf, P. Kourtessis and J. M. Senior, "Upstream Format Map Enhancements for Multi-Wavelength GPONs **(Invited)**,"*13th Networks and Optical Communications* (NOC 2008), Krems, Austria, 2008

[4] Y. Shachaf, P. Kourtessis, and J. M. Senior, "A Full-duplex Access Network based on CWDM-routed PONs,"*Optical Fiber Communication and the National Fiber Optic Engineers Conference* (OFC/NFOEC 2008), San Diego, USA, 2008.

[5] M. Milosavljevic, Y. Shachaf, P. Kourtessis, and J. M. Senior, "Interoperability of GPON and WiMAX for Network Capacity Enhancement and Resilience", *Journal of Optical*

Networking (JON), Optical Society of America (OSA), vol. 8, no. 3, pp. 285–294, March 2009.

2.12 Universidad Politecnica de Valencia - UPVLC

Partner organization name: Universidad Politecnica de Valencia

Short name: UPVLC

Areas of expertise:

The radio-over-fibre distribution of UWB signals can be extended to fibre-to-the-home (FTTH) access networks. This approach was presented in [1] and exhibits several advantages: FTTH networks provide bandwidth enough to distribute a large number of UWB signals, as each one of them can occupy up to 7 GHz in current UWB regulation (FCC 02-48). No trans-modulation is required at user premises. HD audio/video content is transmitted through the fibres in UWB native format. No frequency up-conversion is required at customer premises as the UWB signals are just photo-detected, filtered, amplified and radiated directly to establish the wireless connection. This approach can be extended to 60 GHz UWB technology which is under major attention for broadband communications.

The signal degradation of both UWB modulations (IR-UWB and OFDM-UWB) was analyzed in [2] with 1.25 Gbit/s bitrate (adequate for uncompressed 1920×1080i×18bpp×60 Hz video). The UWB signals were transmitted along different standard single-mode fibre (SSMF) links, ranging from 25 km to 60 km. The experimental results demonstrate the feasibility of the technique achieving a bit error rate (BER) lower than 10^{-9} operation at 50 km SSMF with both IR UWB and OFDM UWB implementations. Nevertheless, IR-UWB presents performance degradation, suggesting that UWB-over-fibre should be accomplished with OFDM signals.

Further investigation on the radio path has been done in [3] for the transmission of MB-OFDM UWB signals in radio-over-fiber (RoF) and the impact of optical transmission in the radio performance. UWB connectivity can be provided at 1.5 m wireless after 10 km SSMF transmission, or 1 m wireless after 50 km, SSMF providing 400 Mbit/s bitrate per user with 0.33 Bit/s/Hz spectral efficiency.

UWB radio can operate in the 3.1 to 10.6 GHz band as defined in current regulation (ECMA-368). First generation UWB systems already available in the market operate in the 3.1 to 4.9 GHz band. This band completely overlaps with IEEE 802.16d/e WiMAX systems operating in the band from 3 to 4.2 GHz (IEEE Std 802.16TM-2004).

The impact of UWB interference on WiMAX at 3.5 GHz band is a relevant research topic and raise regulatory concerns. For this reason, the coexistence problem of UWB radio with narrowband systems is being investigated too in UPVLC.

The simultaneous RoF transmission of WiMAX and UWB on MMF has been carried out in [4] to identify the transmission impairments in a spectral overlapping situation. Simultaneous UWB (employing standard multiband-orthogonal frequency division multiplex MB OFDM, as defined in ECMA-368), and WiMAX (IEEE 802.16d) transmission over low cost multimode fiber (MMF) RoF systems has been demonstrated, including wireless transmission.

Another interesting topic in optical communication research is the polarization multiplexing technique. The distribution of polarization-multiplexed UWB (PM-UWB) signals is a suitable technique for the provision of wireless connectivity to a large number of users maximising the spectral efficiency. This approach provides a higher spectral efficiency and the user capacity is doubled compared with UWB on a single wavelength. The maximum transmission reach of the proposed PM UWB technique has been investigated in [5] demonstrating successful transmission distances up to 25 km for 1.2 Gbit/s aggregated bitrate and 0.76 bit/s/Hz spectral efficiency.

These and other topics in radio over fiber transmission are being investigated in UPVLC.

Relevant Publications:

[1] Roberto Llorente, Manoj P. Thakur, Maria Morant, Stuart D. Walker, Javier Marti, "Performance comparison of radio-over-fibre UWB distribution in SSMF and MMF optical media", ECOC 2008, 21-25 September 2008, Brussels, Belgium, Tu.3.E.2, Vol. 2, pp. 119-120.

[2] R. Llorente, T. Alves, M. Morant, M. Beltran, J. Perez, A. Cartaxo, and J. Marti, "Ultra-Wideband Radio Signals Distribution in FTTH Networks", IEEE Photonics Technology Letters, Vol. 20, No. 11, June 1, pp. 945-947, 2008.

[3] Maria Morant, Joaquin Pérez, Marta Beltran, Roberto Llorente and Javier Marti, "Integrated performance analysis of UWB wireless optical transmission in FTTH networks", The 21st Annual Meeting of The IEEE Lasers & Electro-Optics Society, 2008 LEOS Annual Conference, Newport Beach, CA, 9-13 November 2008.

[4] R. Alemany, J. Pérez, R. Llorente, V. Polo and J. Martí, "Coexistence of WiMAX 802.16d and MB-OFDM UWB in Radio over Multi-mode Fiber Indoor Systems", International Topics Meeting on Microwave Photonics, 2008. Jointly held with the 2008 Asia-Pacific Microwave Photonics Conference. MWP/APMP 2008, Gold Coast, Australia, 30 Sept-3 Oct 2008, pp. 74 – 77.

[5] Maria Morant, Joaquin Perez, Roberto Llorente, Javier Marti , "Transmission of 1.2 Gbit/s Polarization-Multiplexed UWB Signals in PON with 0.76 Bit/s/Hz Spectral Efficiency" Conference on Optical Fiber communication/National Fiber Optic Engineers Conference, 2009. OFC/NFOEC 2009. San Diego, CA, March 2009.

2.13 Summary of research topics

In order to identify the common interests of partners and in order to materialize the initial setup of joint activities some calls (WP23 mailing list) were announced, in which each partner was requested to express its interest on already proposed research topics and/or proposing new topics in order to seek possible partners for planning joint activities. The results of these three calls are summarized in Table 2. As indicated in this table, there are some research topics in this table with one interested partner, but given the inventory of expertise it will be possible to plan further joint activities during the running period of this TP and these projects will be reported in next deliverable (D23.2: Report on Year 1 and updated plan for activities).

Table 2: Research topics and interested partners

Research Topic	Interested Partner(s)[1, 2]
Wireless access technologies in support of networks in motion (RoF)	UDE, UPVLC, AIT, UCAM, UAM, UH
Wireless access technologies in support of networks in motion (FSO)	UDE, AIT, ISCOM, IT,
Switching technologies in support of networks in motion	AIT, ISCOM, IT, UCAM, UAM
Networking protocols in support of networks in motion	AIT, UAM, UH
MAC optimization and design issues for fast base station identification and hand over	AIT, UAM, UH
Converged MAC algorithms for unified optical wireless functionality	**UH**, UCL, AIT
Optimum signalling requirements and resource reservation solutions	AIT, UAM
Fast path identification algorithms and data switching	UH
QoS quarantines in fast reconfigurable networks	UH
Radio over fibre transmission and in the optical beam forming of the antennas	IT,
Millimeter (mm) wave wireless communication systems and 70 GHz radio front-end technology	UDE, IT
UWB Radio-over-fiber transmission in indoor environments using different media	**UPVLC**, AIT
Design and fabrication of coherent and envelope detection wireless photonic receivers	UDE
FSO with studies and experiments for networks in motions solutions.	UDE, UPVLC, AIT, ISCOM,
Hardware implications issues for networks in motion	**Ericsson**, UDE
Optical switching architectures capable of supporting user mobility.	AIT, IT, Ericsson, UAM
Radio-over-fibre techniques for enabling Personal Network concepts	UDE, UPVLC, AIT, IT, UAM
Robust radio-over-fibre techniques	UDE, AIT, IT, UCAM,UH
Node architectures and the control/monument layer requirements	AIT, IT, UAM, UH
Radio over fiber technology with the focus on plastic optical and other MM fiber	UDE, UPVLC, UCAM
Mobile access networks based on free-space optical technology	UDE, AIT, ISCOM,
Optimizing service delivery in a converged hybrid optical-wireless network	**UAM**, TUE, AIT
Protocol routing over hybrid optical wireless mesh networks	UH
End-to-End QoS and Service Delivery over Heterogeneous Network Access	UH
All-optical Routing Architecture of Radio Signals using Label Processing Technique for In-building Optical Networks	**TUE**, AIT
Mitigating the Impact of Traffic Pattern Variations on Multi-Layer Optical Networks	
State of the art definition for components supporting FSO networks in motion	**IT**, ISCOM, AIT

1 - In order to save the space, partners are mentioned in this table with their short names.
2 - The partner who has proposed a JA proposal is presented in Bold typeface.

3. Proposals for Joint Activities

Based on common interests of partners the following joint activities are planned. Given the inventory of expertise, which is also circulated among the partners, it is possible to have more joint activities during the term of this TP. These activities will be reported in the next deliverable of this TP (D23.2).

3.1 Hardware implications issues for networks in motion

Participants: Ericsson, UDE
Responsible Person(s): Rebecca Chandy (rebeccachandy@gmail.com)
Description: Reliability of Components and Hardware implications issues for networks in motion Sensor applications
Outcome of the join research activity: Improved design and reliability of hardware for networks in motion
Type of work: Theoretical and Experimental
Expected Duration: Two Years
Targeted call for papers (Conf., Journal, Workshops,…): To be confirmed
Other comments: N/A

3.2 State of the art definition for components supporting FSO networks in motion

Participants: IT, ISCOM, AIT
Responsible Person(s): António Teixeira (teixeira@ua.pt), Girogio Tosi-Beleffi, Ioannis Tomkos
Description: Nowadays with the increasing demands on data rate several options become important to observe. Specially when moving above tens of gigabits/s the limitations in the propagation and spectrum allocation are visible and relevant. Therefore it is important to observe the possibilities to explore several other options specially to transmit these high data rates and that could be compatible to the other existing and upcoming technologies. FSO (free space optics) is one of the options since it allows high data rates and at the same time is highly directive and can be generated without complexity directly from a fiber end just recurring to a lens. The latter gives it high flexibility and compatibility to the existing PON's structures. In this work it is envisaged to collect some of the existing techniques and component features that can be of usage in the support of FSO with mobility.
Outcome of the join research activity: - A revision on the application of FSO to networks in motion - A paper on the subject
Type of work: Theoretical/Experimental
Expected Duration: continuous- 2 years.
Targeted call for papers (Conf., Journal, Workshops, …): [To be finalized]
Other comments: Skills /facilities available: FSO System and characterization test-bed.

3.3 Converged MAC algorithms for unified optical wireless functionality

Participants: UH, UCL, AIT
Responsible Person(s): Pandelis Kourtessis p.kourtessis@herts.ac.uk Milos Milosavljevic m.milosavljevic@herts.ac.uk, Christos Tsekrekos (AIT)
Description: To implement dynamic resource allocation by means of wireless propagation by conventional NRZ, over PONs, it is important to design a unique control layer adhering to service level agreement (SLA) and service differentiation. However, the classical DBA schemes employed to provide QoS and SLA in PONs are difficult to be applied in converged PON and wireless networks due to the distinct transmission, bandwidth management methodologies and packet formats. To enable more efficient integration, an effective mapping mechanism is required between PON priority queues and wireless service connections. Specifically, the mapping needs to know which wireless flow should be stored in which PON priority queue for equivalent QoS. In addition, PON supports QoS in a DiffServ mode, under which packets are classified and stored in different priority queues. In contrast, although the services of legacy wireless are classified to support different levels of QoS, LTE like WiMAX and WiFi is a connection-oriented technology, which essentially follows an integrated service (IntServ) mode. Thus, for integration, an interesting problem is how to make efficient conversions between Diff-Serv and IntServ services. In addition, it is also interesting to see how the end-to-end QoS can be supported after these two systems are integrated.
Outcome of the join research activity: Unified MAC protocol for legacy PON and wireless networks. This would be expected to lead to hardware implementation at a later stage of the underlying network architecture.
Type of work: OPNET Simulations
Expected Duration: 2 years
Targeted call for papers (Conf., Journal, Workshops, …): OFC2010, ECOC2010, IEEE JLT IEEE/OSA JOCN
Other comments: {optional} Skills/facilities required: OPNET programming Skils /facilities available: OPNET Modeler simulation platform

3.4 UWB Radio-over-fiber transmission in indoor environments using different media

Participants: UPVLC, AIT (Christos Tsekrekos)
Responsible Person(s): Roberto Llorente / rllorent@dcom.upv.es
Description: Two main UWB implementations are being further developed nowadays. From one side, WiMedia-defined signals which are based on multi-band orthogonal frequency division multiplexing (MB OFDM) modulation that has been adopted in the standard ECMA-368 specification. From the other side, impulse radio (IR) technology signals increases the accuracy as employs short radio pulses, typically in the picoseconds range. IR-UWB is able to provide high-speed communications, localization and ranging simultaneously. The proposed work comprises the radio-over-fiber transmission of both OFDM and IR UWB signals for in-building applications, e.g. offices or home environments, over different media as standard single mode fiber (SSMF), multimode fiber (MMF), plastic optical fiber (POF) or others.
Outcome of the join research activity: Study of the performance of UWB signals in radio-over-fiber transmission for in-building applications in terms of quality of signal, bitrate, spectral efficiency, fiber maximum reach and others, considering, if possible, the effects of the fiber transmission on the UWB radio path.
Type of work: Experimental and simulation if necessary
Expected Duration: 1 Year
Targeted call for papers (Conf., Journal, Workshops,…): [To be finalized]
Other comments: N/A

3.5 Optimizing service delivery in a converged hybrid optical-wireless network

Participants: UAM, AIT, TUE
Responsible Person(s): Bas Huiszoon (bas.huiszoon@uam.es) , Ioannis Tomkos (itom@ait.edu.gr), Ton Koonen (a.m.j.koonen@tue.nl)
Description: In this Joint Activity a hybrid optical-wireless network is studied which supports next-generation broadband fixed/mobile converged networking. The overall aim is to optimize the service delivery and resource usage when a user is moving around in the network. This can be done in many ways; however, this JA focuses on providing re-configurability in various networking layers and dynamic mechanisms in order to quickly adapt the network configuration to accommodate broadband mobile networking. The research takes into account both the fixed and wireless tier.
Outcome of the join research activity: Key solutions in various networking layers, such as network architectures, protocols (MAC, signaling …), or tools (monitoring, classification …). Verification and benchmarking of the realized innovations with respect to existing solutions.
Type of work: Theoretical, simulation, and experimental validation.
Expected Duration: Continuous, during the whole duration of WP23.
Targeted call for papers OFC 2010, 2011, … ECOC 2010, 2011, … IEEE/OSA Journal of Lightwave Technology OSA/IEEE Journal of Optical Communications and Networking
Other comments: This JA actively seeks collaboration with other (future) EU projects.

3.6 All-optical Routing Architecture of Radio Signals using Label Processing Technique for In-building Optical Networks

Participants: UAM, TUE, AIT

Responsible Person(s): Bas Huiszoon (bas.huiszoon@uam.es), Ton Koonen (a.m.j.koonen@tue.nl) , Christos Tsekrekos (AIT)

Description:

The growing demand of broadband services among residential and business customers has fuelled the research and development of numerous wired and wireless technologies to satisfy those demands. Radio-over-fibre (RoF) technology is considered as a key enabler for merging of broadband wired and wireless services in an integrated full service access and in-building networks [1]. In addition, RoF distributed antenna systems are identified as a flexible option for the access architecture of current and emerging wireless access in-building networks as it reduces infrastructure costs and antenna site complexity.

Figure 1 shows an example of in-building access architecture. In this architecture, the main device is the home communication controller (HCC), which arranges communications between rooms and routes signals to the proper rooms according to the label information attached to the data signals. Optical routing based on label information will improve the flexibility and the efficiency of the network resources.

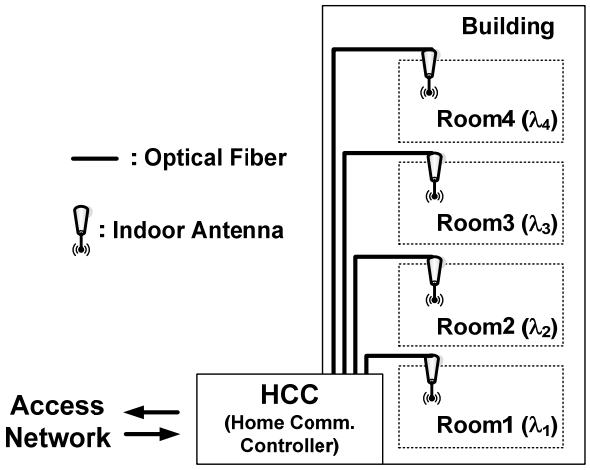

Fig. 1: In-building network architecture

In this joint activity a new all-optical HCC architecture that forwards the radio signal to the specific rooms based on the label information will be investigated.

[1]. T. Koonen et al OFC'07, OThP3, 2007

[2]. N. Calabretta et al, OFC'08, PDP33, 2008

Outcome of the join research activity:

A new all-optical HCC architecture for routing of RoF signals with label-processing

technique will be experimentally investigated.
Type of work: Experiments/Development
Expected Duration: 2 years
Targeted call for papers OFC 2010, 2011 ECOC 2010, 2011 IEEE/OSA Journal of Lightwave Technology OSA/IEEE Journal of Optical Communications and Networking
Other comments: This JA actively seeks collaboration with other (future) EU projects.

3.7 Summary of joint activities

Table 3 contains the key information regarding the Joint Activities that are planned so far. In addition to the current planned activities, and given the inventory of partner expertise; it is possible for all participants in this TP (WP23) to plan other new activities during the term of this topical project. As it is presented in this table, **6** joint activities with 3 initial mobility actions are planned for this work package. The duration of most of the joint activities covers the two years of the project.

Table 3: Summary of planned joint activities

No.	JA Title	Contact Person	Participants	Mobility Action	Deadline
1	Hardware implications issues for networks in motion	Rebecca Chandy rebeccachandy@gmail.com	Ericsson, UDE		M36
2	State of the art definition for components supporting FSO networks in motion	Antonio Teixeira (Teixeria@ua.pt)	IT, ISCOM, AIT	Yes	M36
3	Converged MAC algorithms for unified optical wireless functionality	Pandelis Kourtessis p.kourtessis@herts.ac.uk Milos Milosavljevic m.milosavljevic@herts.ac.uk	UH, UCL, AIT		M36
4	UWB Radio-over-fiber transmission in indoor environments using different media	Roberto Llorente rllorent@dcom.upv.es	UPVLC, AIT		M24
5	Optimizing service delivery in a converged hybrid optical-wireless network	Bas Huiszoon (bas.huiszoon@uam.es) , Ioannis Tomkos (itom@ait.edu.gr), Ton Koonen (a.m.j.koonen@tue.nl)	UAM, TUE, AIT	Yes	M36
6	All-optical Routing Architecture of Radio Signals using Label Processing Technique for In-building Optical Networks	Ton Koonen (a.m.j.koonen@tue.nl) Bas Huiszoon (bas.huiszoon@uam.es)	UAM, TUE, AIT		M36

4. Conclusions

The proposal of joint activities and their research criteria adequately cover almost all the planned research objectives of this work package as indicated in the BONE Annex I (Description of Work). Publications in international conferences and journals are almost assured thanks to the amount of partners and their expertise. Moreover, mobility actions, which will be performed in this work package, will increase the interaction among the research groups, which are participating in this work package, which is a secondary objective of this Network of Excellence. Furthermore the inventory of expertise enables the partners to initiate more joint activities during the term of this TP (WP23).