Fiber-to-the-PAN: Towards Optical in Personal Networks

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The optical domain offers a great potential towards a realization of the envisaged future personal network around the user's Personal Area Network (PAN). We introduce Fiber-to-the-PAN as a method to increase the transparency in the access network. We studied the implications on the network design of using optical communications in the personal network.

Introduction

The PN concept is introduced in [1] and involves *wireless* access of PAN devices to a global infrastructure for ubiquitous integrated (anytime, anywhere, anything) service delivery. Current studies briefly consider optical communications in PNs. In this paper, the concepts PN, Fiber-to-the-PAN and Island of Transparency are highlighted. Implications on optical network design are discussed and interoperation with (emerging) wireless technologies is addressed.

Personal Network concept

Wireless networks show a rapid growth and research visions agree that the user will have a central position in his wireless environment [2-3]. A PAN refers to a small network space around a person constituted by portable wireless networking devices. Typical PAN devices are a notebook computer or a Personal Digital Assistant (PDA). The local scope of a PAN (e.g. synchronizing the PDA with the notebook) is extended to a global scope when remote resources and virtual private environments are involved (e.g. accessing a remote corporate server with the notebook). As such, a user has its PN when it is able to use a service of a remote environment with a PAN device. This is shown in Figure 1 for a Core and Cell PAN.

Introducing Optical in PNs

The current state of technology already allows basic PNs to exist. However, a high degree of heterogeneity is present in interconnected telecommunication networks (twisted pair, coax, radio, satellite, fiber). Due to historical developments each access network is designed for a different class of services. This heterogeneity amongst access networks is very (cost) inefficient today whereas functionality is lost and complexity is increased. As a fixed medium the optical fiber is able transport a diversity of services to multiple users due to its signal transparency, large bandwidth and low losses. The signal transparency gives the fiber multi-standard abilities and makes it future-proof with respect to bit rates and signal formats. The low losses enable a high degree of network scalability and require less active devices thus decreasing installation, operating and maintenance costs. The extra dimension of optical wavelength enables routing in the

physical domain. This reduces complexity, costs and delay in the network due to the absence of optical-electrical conversion and a reduced protocol stack.

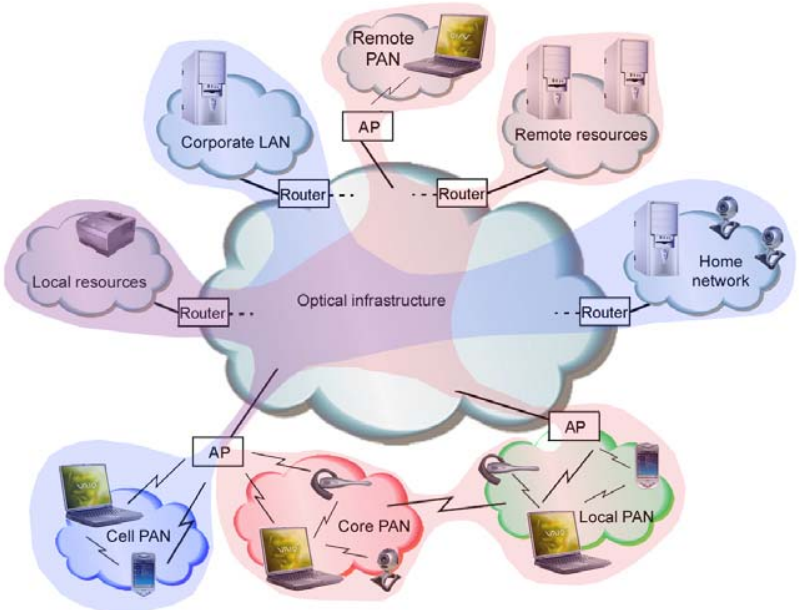

Figure 1: Two active personal networks sharing medium and resources (modified from [1])

Network Transparency

The fiber is already present in today's network architecture, but the optical lightpath is limited in its global and local reach. Globally, O/E/O and wavelength conversion create opaque and semi-transparent bridging of network segments that interrupt the lightpath. Locally, the fiber is positioned relatively high in the network thus restricting large scale user access. The bounded segments are referred to as Islands of Transparency (IoTs). Each individual PAN operates as such on its own IoT. A transparent communication path can be established, if the IoTs of different PANs overlap. This is shown in Figure 2 where a transparency exists on the Core and FTTX levels between the Home Network and the Local PAN.

To maximize transparency, the inner and outer diameters of the IoT should be reduced and enlarged respectively. Introducing the fiber in the local loop is referred to as Fiber-to-the-X where X stands for the location (Exchange, Cabinet, Curb, Home) of the optical networking unit or access point at the end of the network. Fiber-to-the-*PAN* as such reduces the inner diameter of the IoT significantly as shown in Figure 3. The outer diameter of the IoTs can be enlarged by using all-optical signal handling, for example by using all-optical 3R regenerators or all-optical switches.

Fiber-to-the-PAN

If the fiber reaches the PAN the wireless PAN networks are fed from the fiber. Next-generation wireless PAN technologies should provide higher data transmission rates

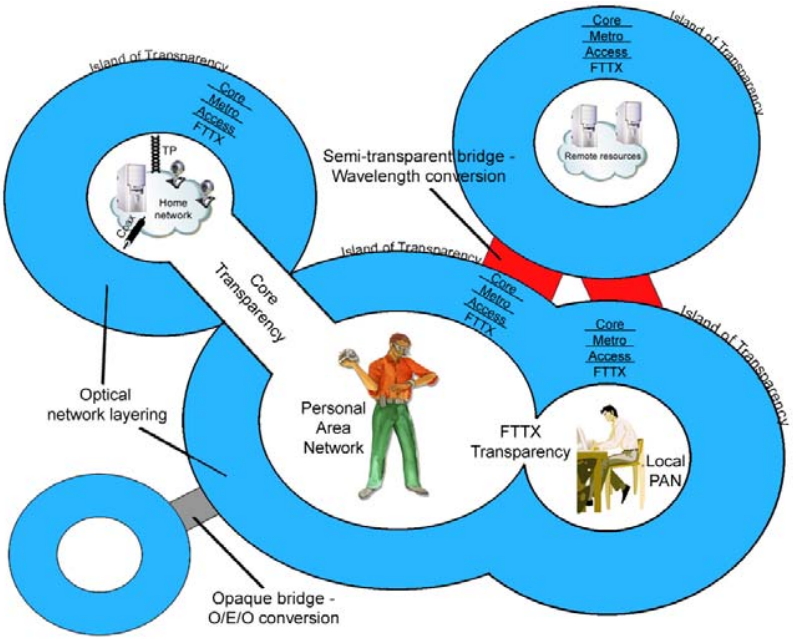

Figure 2: Network layer transparency between Islands of Transparency

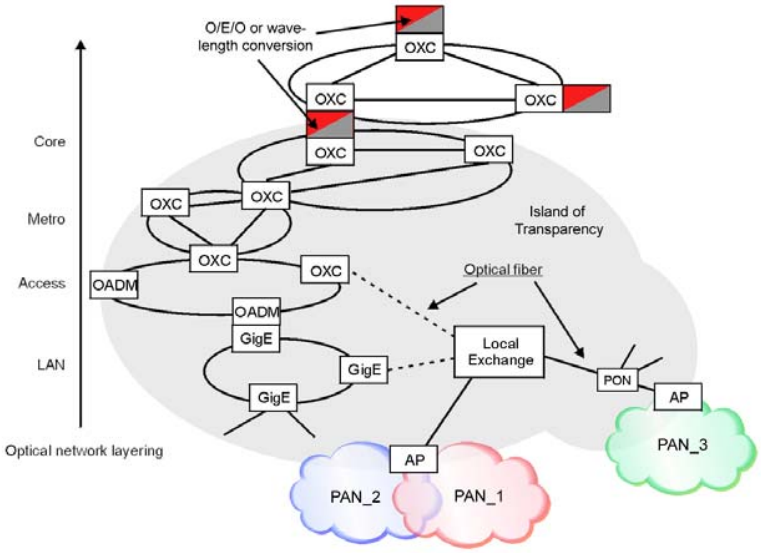

Figure 3: Fiber-to-the-PAN enlarges the Island of Transparency

than existing 3G technologies. The next-generation technologies include Ultra-Wide Band (UWB), Wireless Optics (WO) and TeraHertz (THz) communications [4]. The wireless links aggregate their traffic at a network Access Point (AP) where the data is transported to a central node or Local Exchange (LEX) which is placed deeper in the network. Aggregated payloads can reach in the future significant values (>100 Mbps) [5]. As shown in Figure 3, the network position of the LEX is to be assessed, hence the dashed lines. The LEX might well be the position where the circuit-switched data paths

towards the PAN are converted to packet-switched data paths of the higher network layers. The network topology allows for point-to-point or point-to-multipoint Passive Optical Network (PON) concepts to be considered in various flavors.

A robust Multiple Access (MA) technique has to ensure separation of data streams and to allow a wide variety of services and networks to co-exist in the fiber. Well-known MA techniques are MA by time, wavelength, sub-carrier, and code. Space division MA is not considered here. Not all MA techniques are suitable to be used on a PN network employing FTTPAN. For example, time MA raises difficulties in the synchronization of LEX and AP device due to the large fiber distances.

Personal Network Services

Ultimately, when optical communications opens up the last-mile and large Islands of Transparency are present in higher network layers, the bottleneck shifts towards global traffic management and the service providers. Specific services such as voice traffic have stringent QoS requirements of the network (latency, packet error rate, etc.). Global service delivery is highly dependent on the QoS that networks and service providers are able to provide in terms of latency, frame/packet error rate, connection set-up time, reliability, etc. Five service classes are defined, namely data transfer, (home) control, video, audio, and voice/telephony according to their requirements on QoS. The delivery of video services (including streaming, games, and tele-conferencing) is considered as an important future service and the only service to be able to sizably load the network.

Conclusions

To employ optical communication technologies in the Personal Network (PN) concept is an attractive option to alleviate boundaries set by today's and near-future's networking technologies.

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