Technology Digest

For limited circulation

Monthly bulletin of telecom technology

Issue 4, October 2011

Telecom Regulatory Authority of India

NEXT GENERATION OPTICAL ACCESS NETWORKS

In this issue

Next Generation Optical Access Networks P1
Role of Devices for Video Consumption P3
Ingredients for the Network of the Future P6
Smartphone Application Processors P8

New applications, networks, online tools and cloud computing are putting greater strains on the existing bandwidth capacity of networks and pushing broadband capabilities to their limits. Access networks have, so far, struggled to keep pace with the explosion in bandwidth consumption caused by the growing number of bandwidth-intensive applications.

Next Generation Optical Access (NGOA) promises to deliver the required bandwidth for current and future applications. NGOA is a network that relies on optical fibers from the access to the core. It increases the access layer bandwidth and builds a future proof access layer network. Once in place, this network architecture provides high bandwidth both upstream and downstream, ensuring ample bandwidth to enable applications such as 3D HDTV, video telephony and cloud computing. NGOA has the capability to improve business facilities, public services, health, education, and government services. It will pave the way for smarter energy grids, smarter transportation and environmental systems making activities more efficient and effective. NGOA will lay a foundation to develop new and groundbreaking services and facilities and pave the way for a faster, efficient and a more innovative digital society.

What is Next Generation Optical Access (NGOA)?

According to European Commission the term Next generation access (NGA) networks refers to wired access networks which consist wholly or in part of optical elements and which are capable of delivering broadband access services with enhanced characteristics as compared to those provided over already existing copper networks. BT describes NGA as internet that uses next-generation optic fibres, rather than the copper wires which most broadband users in the UK use at the moment.

NGOA are access networks that are completely fibre based. They have been described by various organisations involved in related research in different ways. One such description is given by the OASE Integrated Project, funded by European Union's Seventh Framework Programme (FP7/2007-2013) federating partners from major operators, industrial leaders and universities in Europe. Some of the key requirements for a Next Generation Optical Access (NGOA) system and architecture design have been identified as follows:

Service:

- Full service access with high quality, accessibility, retainability and security
- FTTH residential peak data rates ≥1 Gbit/s
- Business, backhaul (fixed, mobile) peak date rate: ≥10 Gbit/s
- RAN transport: Low delay, synchronization
- Average sustainable downstream based on peak-hour service usage of 500 Mbit/s per Optical Network Unit (ONU)/customer
- Support of more traffic symmetry, with ratio of at least 1:2 between upstream and downstream
- QoS support with at least four QoS classes

Network:

- Support from 256 to 1024 ONUs/customer per feeder fibre
- Support of 128 Gbit/s to 500 Gbit/s aggregate capacity per feeder fibre
- Support of 20 to 40 km passive reach option for the working path
- Support of 60 to 90 km extended reach option for the protection path
- Legacy Optical Distribution Network (ODN) compatibility desirable
- Flexible and agnostic interfaces (optical and service layers)
- Security better than XG-PON1

Operations and Business:

- Support of co-operations, e.g. open access (e.g. L1, L2, L3)
- Low power consumption
- High availability options
- Support of auto-configuration, remote-management and network monitoring to automate operation processes: provisioning, maintenance and fault management
- Simplification of operational processes by suitable network design

Advantages of NGOA

- Symmetrical and high capacity
- Long life and future proofed infrastructure
- Service agnostic architecture
- Uncontended bandwidth with low latency
- Scalability
- Cost effectiveness over the lifecycle
- Open access infrastructure
- There is no comparable technology known to the global scientific community

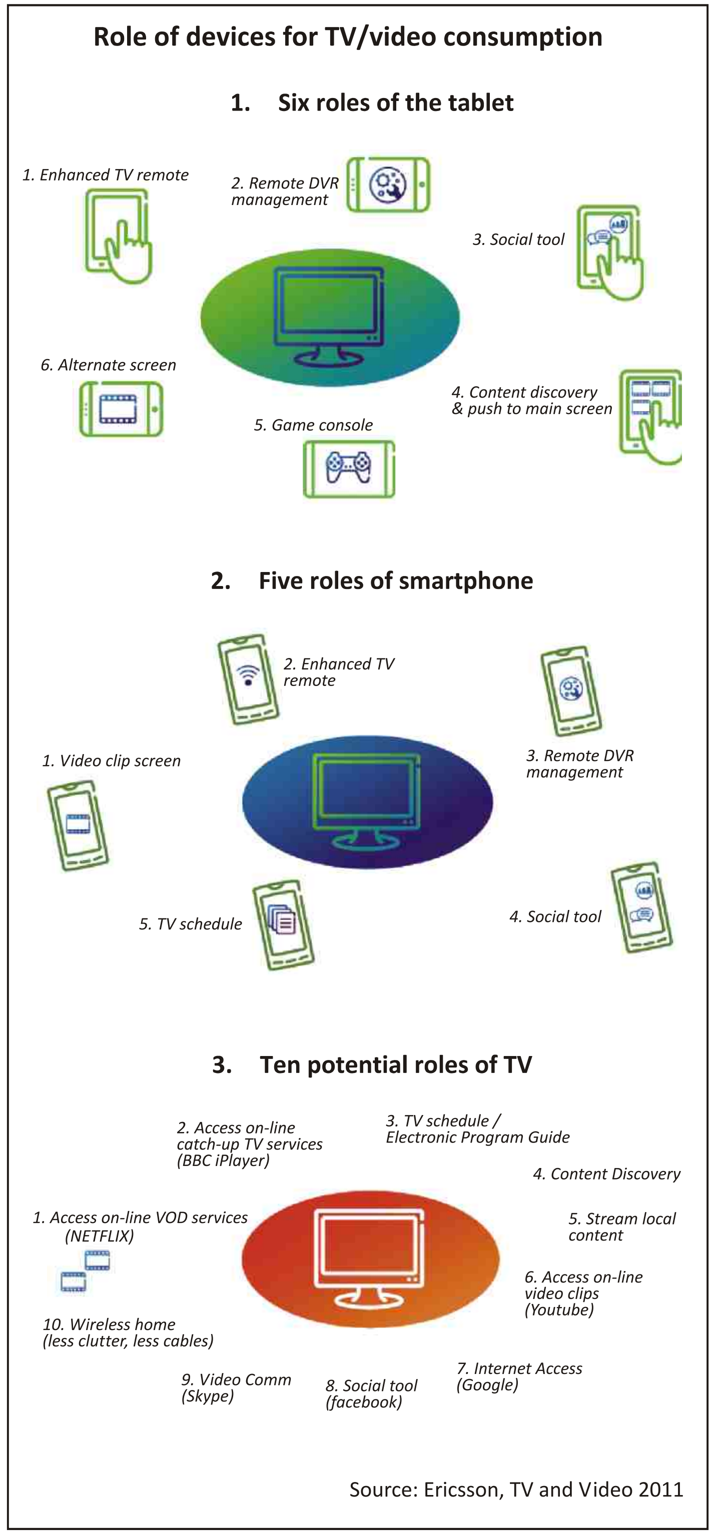
Architecture of NGOA

In a standard Passive Optical Network (PON) system, a single fiber runs from the central office to a neighborhood, at which point a passive splitter splits the optical signal into a number of beams on different fibers to different homes or offices. Each PON has an Optical Line Termination (OLT) at the Central Office(CO) and a Optical Network Unit (ONU) at the customer premises. There are no active components between the central office and customer's premises, which eliminates the need to power and manage active components in the external network. The PON has a tree topology in order to maximize their coverage with minimum network splits, thus reducing optical power loss. Virtually all PON technologies rely on some form of wavelength division multiplexing (WDM) to enable bi-directional communications. For example, in a typical Gigabit PON (GPON) system, the upstream communication runs at 1310 nm wavelength, while the downstream traffic runs at 1490 nm. However, in a typical GPON or Gigabit Ethernet PON (GEPON) system all subscribers use those same common wavelengths. This means they have to share the fiber infrastructure, which is done through time division multiplexing (TDM). Each of those homes/offices transmits over the same fiber, but in the time slot allocated by the optical line terminal (OLT) at the central office. While the equipment in each home or office is capable of transmitting at over 1.25 Gbps or 2.5 Gbps, it can only do so during its allotted time on the fiber, and therefore it is not uncommon for each subscriber in a legacy PON system to only achieve sustained data rates of around 30 Mbps. OLTs are housed in a shelf that typically supports multiple OLTs with common control, power modules and interfaces to voice and data services equipment.

Traditional and emerging NGOA technologies

Traditional PON architectures such as ATM PON (APON), Broadband PON (BPON), GPON and Ethernet PON (EPON) use Time Division Multiple Access (TDMA) to share bandwidth among subscribers on a common fiber. Dynamic Bandwidth Allocation (DBA) algorithms are used to decide who gets the available bandwidth at times of oversubscription. This time-based separation of subscribers within fixed aggregated data rates has made it difficult for traditional PON protocols to scale to meet the changing bandwidth requirement. Two main FTTH-PON standards that are currently deployed around the world are EPON, approved in 2004 (IEEE 802.3ah, 2004); and GPON, developed by Full Service Access Network (FSAN) in 2003 (ITU-T G.984.[1-4], 2003). In both solutions, the equipment installed in the field is fully passive, covering distances of up to 20 km, using a point-to-multipoint topology, providing wider bandwidth to the end user, and allowing video broadcasting. The split-ratio is variable – commonly, an average of 32 to 64 users. In fact, the basic physical features for both standards are very similar – what makes them more different is the Media Access Control (MAC) protocol and the data encapsulation scheme. While EPON carries bursts of pure Ethernet frames, GPON encapsulates data using Generic Encapsulation Method (GEM). The bit rate is symmetric, up to 1-1.25 Gb/s – therefore, the maximum bandwidth allocated to each ONU is typically around 70 Mb/s, though it depends on the number of active ONUs and the users' traffic profiles.

The traditional technologies have certain limitations. In a TDM-PON with non-wavelength selective splitters (1:32, 1:64 or 1:128), N+1 non-colour transceivers are needed, and these must be able to operate at the aggregate bit rate. In the case of GPON these are 2.5Gbit/s transceivers, delivering (less than) 1/32, 1/64 or 1/128 of the aggregate 2.5Gbit/s signal as a Committed Information Rate (CIR) to the subscriber. It is easy to see that a CIR of 1Gbit/s that the next generation access technologies can offer is nearly impossible to deliver. Another limitation of traditional PON systems is the reach. The insertion loss of a 1:32, 1:64 or 1:128 splitters is between ~17dB and ~22dB, respectively, compared to ~4dB insertion loss for a WDM filter. These splitters take away at least 40km of precious fiber budget. The TDM-PON, while being able to fulfill today's bandwidth requirements, are not suitable to support important long-term goals such as site reduction and CO consolidation, scalability, reach and fair and efficient bandwidth allocation to users.



Source: Ericsson, TV and Video 2011

The trends for Next Generation Access (NGA) based on PON include advanced multiplexing schemes, 10 Gb/s or more bandwidth, higher splits and longer reach. At the forefront of PON development there have been three separate approaches that appear to compete for next-generation systems: 10 Gbps PON (10G EPON or 10G GPON whose standards were finalized in 2009 and 2010 respectively), Wavelength Division Multiplexing PON (WDM-PON) and Orthogonal Frequency Division Multiplexing PON (OFDM PON). Each approach has its own advantages and its own issues, but the progress with the new technologies has accelerated in recent years. In this issue we will focus on WDM-PON and OFDMA-PON as viable technologies for NGOA.

WDM-PON

Standards bodies, equipment vendors and service providers have struggled to keep pace, transitioning from A- to B- to GPON, with now talk of NG-PON alternatives. This inability to scale has been one of the major shortcomings of traditional PON protocols and has driven the search for better alternatives. Network operators need a more cost-effective and scalable approach to subscriber separation. They need more flexibility, and they need to be able to deliver high-bandwidth, low-latency service performance over significantly longer spans of fiber than the 20 km that TDM-PON typically supports. Introducing WDM into the access part of the network allows consolidation into a single architecture that backhauls traffic to centralized data centers and switches at the lowest layer possible. By avoiding multiple layers of data aggregation and protocol conversions, a dramatically more efficient access network can be built that supports the long-term strategy to eliminate active sites and consolidate CO, while scaling indefinitely to meet future demand. Initially the adoption was slow because of high cost compared to GEPON and GPON technologies but that is changing now.

WDM technology has certainly been one of the great bandwidth enablers over the last decade in the transport network. As WDM technology matured, it moved from the core of the network toward metropolitan networks, eventually reaching the edge of access. However, when vendors tried to extend the technology for access networks, it proved a poor fit. Price points were too high. The colour-stabilized lasers and multiplexers were power hungry and not able to operate over the extended temperature extremes required of field boxes. Simply separating subscribers by colour was inefficient, as well as ineffective. There was no way of knowing status or measuring performance on the end-to-end path to the customer. The solution to all of these problems arrived with environmentally-hardened WDM filters that allow the creation of a point-to-multi-point WDM solution, often referred to as passive WDM or WDM-PON. Scalability issues are resolved by reserving colours on an individual or group of subscriber basis, rather than through time-slot reservation. Colour-stabilized lasers are only required in the end-points of the network, and only the temperature-hardened Flexible Remote Node (FRN) needs to be fielded.

The system architecture in a WDM-PON network is not significantly different from that of a more traditional GEPON or GPON system, although exactly how the network operates is entirely different. Figure below illustrates a high-level view of WDM-PON.

The OLT, which resides at the CO, has an array of transmitters and receivers. Each transmitter-receiver pair is set at the wavelength band of the port of the multiplexing device, in this case an Arrayed Waveguide Grating (AWG), to which the pair is connected. In some cases, especially when the expected load of the network is low and bursty, the array of transmitters may be replaced by a set of fast tunable transmitters that are dynamically shifted from one wavelength to the next one. In this case, the number of tunable devices can be much less than the number of ONUs. After the OLT, a Single Mode Fiber (SMF) acts as a feeder fiber to a Remote Node (RN, not labeled) here another multiplexing device sits. Each port of the AWG at the RN is connected to a different ONU. Each ONU has a passive splitter that is connected on one end to a tunable transmitter and on the other to a receiver. In this particular architecture, the receiver needs not to be tunable, since the AWG will only allow the assigned wavelength to arrive to the ONU. The receivers may optionally be tunable, if there is a need to have splitters / couplers between the RN and the ONU. Some alternatives for the design of WDMPON ONUs are tunable laser diodes, broadband light sources with spectral slicing, Fabry-Pérot laser diodes with injection locking and centralized light sources.

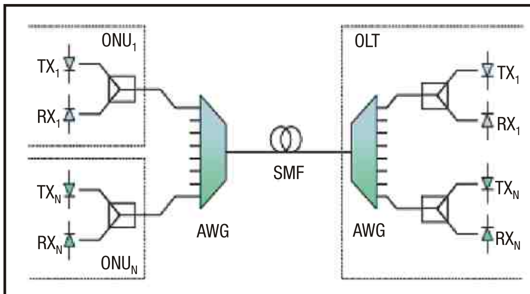


Figure: WDM-PON Architecture

There are several advantages to the WDM-PON architecture over more traditional PON systems. Foremost of course is the bandwidth available to each subscriber. Second, WDM-PON networks can typically provide better security and scalability, since each home only receives its own wavelength. Third, the MAC layer in a WDM-PON is simplified, since WDM-PON provides Point-to-Point (P2P) connections between OLT and ONT, and does not require the Point-to-Multipoint (P2MP) media access controllers found in other PON networks. Finally, each wavelength in a WDM-PON network is effectively a P2P link, allowing each link to run a different speed and protocol for maximum flexibility and pay-as-you-grow upgrades.

The main challenge with WDM-PON is cost. Since each subscriber is assigned his own wavelength this suggests that the OLT must transmit on 32 different wavelengths versus one shared wavelength as found in more traditional PON systems. Likewise, it requires that each of the 32 homes on a link operate at a separate wavelength suggesting that every ONT requires an expensive tunable laser that can be tuned to the correct wavelength for a particular home. This would be very cost prohibitive, particularly in initial set-up costs, and was a major hurdle in early design of WDM-PON systems. Lower operational expense may be achieved with operational simplicity (less and simpler active equipment), lower energy consumption and fewer active sites. To accomplish all three requires a technology that supports high capacity and long reach. WDM has delivered against these requirements in other parts of the network. There are three types of colourless WDM-PON solutions under development for access networks:

Reflective schemes: where the upstream optical carrier is remotely generated (typically at the C.O.) and sent to the ONT, where it seeds a modulating device.

Tunable lasers at the ONTs: where the upstream optical carrier is locally generated at the ONT. This is still a costly option, but ongoing research as well as the maturing of the technology in the industry will drive down costs over time.

Wavelength reuse: is a solution where the downstream channel is re-modulated by the upstream signal and sent back to the CO.

The figure below shows the above schemes diagrammatically:

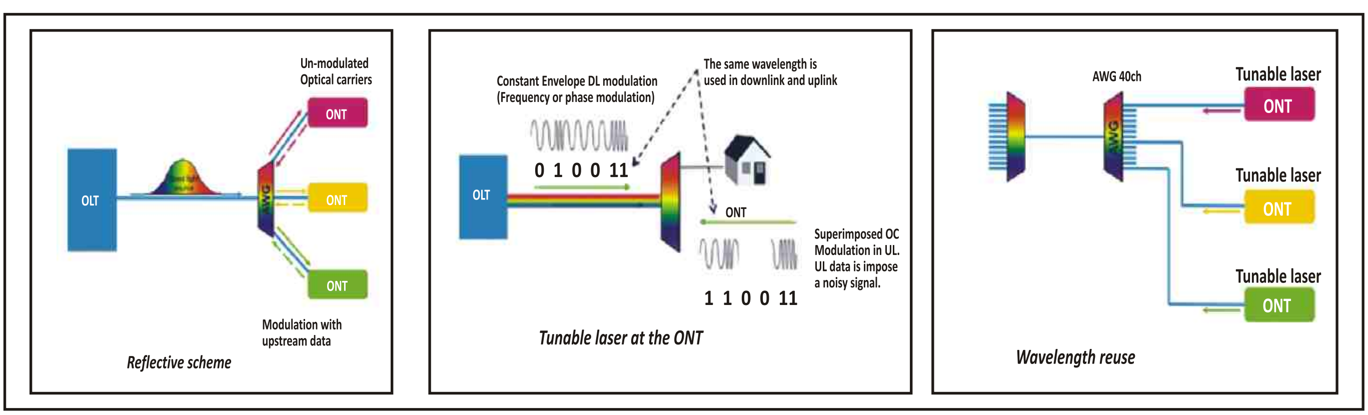


Figure: Schemes for WDM-PON Solution

In a total cost of ownership study cost of WDM-based NGA were compared with two of today's most prevalent high-bandwidth access architectures, VDSL2 and GPON. It was found that while VDSL2 has the lowest duct costs its provisioning and O&M costs were the highest. Energy costs were 18% of the total cost of ownership. GPON and WDM-based networks, on the other hand, required significant build out of the fiber plant leading to high duct cost. Both fiber solutions allow a reduction of energy cost compared to the VDSL2 approach with a slight advantage for the WDM-based NGA. The overall operational expense for GPON was more than 50% higher than for the WDM-based NGA, mainly due to the higher number of sites with active equipment. Normalized to the VDSL2 case, GPON does not provide any TCO advantages, whereas the WDM-based NGA provides 20% savings. The WDM-based NGA approach saves operating expenses and lowers energy use over the life of a network, easily offsetting any additional capital expense up front.

OFDMA-PON

OFDMA-PON is a novel DSP-based platform for speed, flexibility and cost-efficiency in future high-speed PON access systems. It is under development and trial phase. It is critical that future PON technologies be highly cost-efficient to remain attractive and practical. This is sought to be achieved by re-use of existing optical distribution network (ODN), upgrading with advanced modulation and advanced digital signal processing (DSP). The OFDMA-PON is different from other technologies for the following reasons:

- It tackles key challenges in the electronic domain through digital signal processing (DSP)
- It leverages advanced DSP to achieve superior performance, rapid and robust network re-configurability, cost reduction
- Integrated DSP-based transmission and control planes

Content, Connectivity, and Cloud: Ingredients for the Network of the Future

The Internet architecture has coped so far with a sustained continuous development and provided a good environment for a wide range of applications. Nevertheless, this model is now being challenged, not only from the technical viewpoint, but also from the business one. A new network architecture for the Internet needs ingredients from three approaches: information-centric networking, cloud computing integrated with networking, and open connectivity.

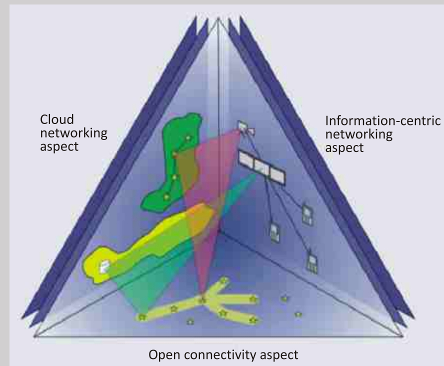


Figure: Three aspects of new network architecture

Information-centric networking considers pieces of information as main entities of a networking architecture, rather than only indirectly identifying and manipulating them via a node hosting that information; this way, information becomes independent from the devices they are stored in, enabling efficient and application-independent information caching in the network. Major challenges include global scalability, cache management, congestion control, and deployment issues. Cloud networking offers a combination and integration of cloud computing and virtual networking distributing the benefits of cloud computing more deeply into the network. Open connectivity services need to provide advanced transport and networking mechanisms and dealing with ubiquitous mobility of user, content and information objects in a unified way.

Source: IEEE Communications Magazine, July 2011

- OFDM sub-carriers become transparent pipes for delivery of arbitrary signals (e.g. T1/E1, Ethernet, RF mobile backhaul, IPTV, VPN, etc..)
- Bandwidth dynamically assigned to different services in different time slots
- System is transparent, flexible and extensible to any emerging applications

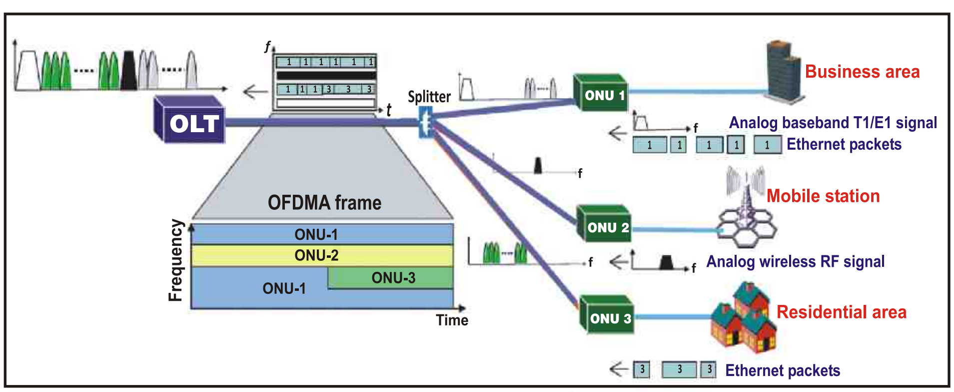


Figure: OFDMA-PON architecture

Variants of OFDMA-PON

The following variations of OFDM-based PON for Multi-User Access are under consideration:

i) OFDMA-PON: Different users assigned different OFDM subcarriers within one OFDM band of total N subcarriers

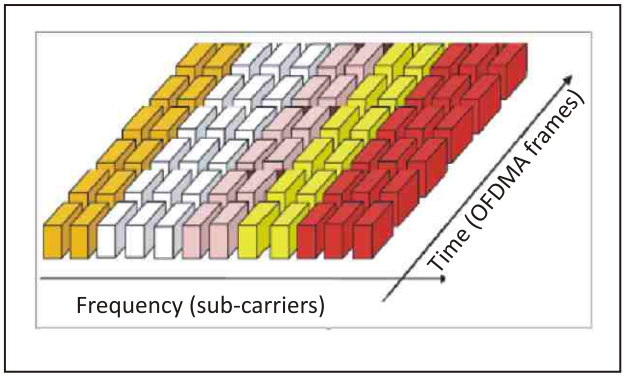


Figure: OFDMA-PON

ii) OFDMA + TDMA PON: Different users assigned different OFDM subcarriers and TDM slots within one OFDM band; 2-dimensional dynamic bandwidth allocation

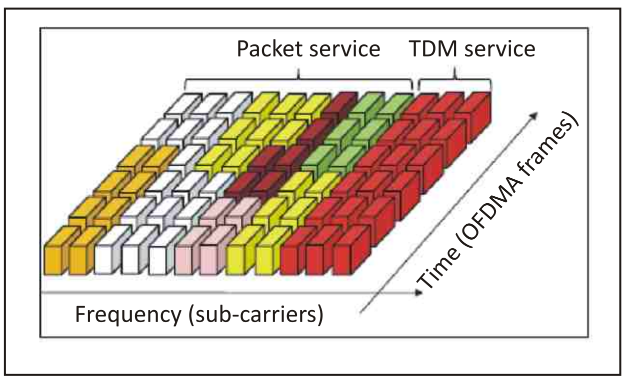


Figure: OFDMA + TDMA PON

iii) OFDMA + TDMA + WDMA: PON: Different users assigned different OFDM subcarriers, and TDM slots and WDM

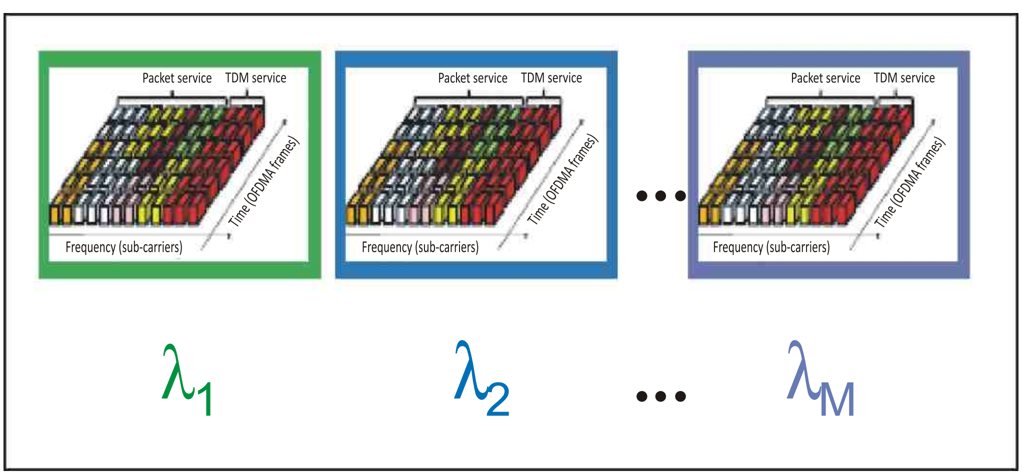


Figure: OFDMA + TDMA + WDMA PON

Benefits of OFDM-PON

i) Speed and Distance
- Up to 100 Gb/s/λ downstream transmission
- Up to 100 Gb/s/λ upstream transmission
- Up to 100km reach for PON, 1000km for metro

ii) Flexibility
- Adaptive modulation and Forward Error Correction(FEC) on subcarrier basis
- Dynamic bandwidth allocation in time and frequency
- Transparency to arbitrary services
- Optically-transparent ONUs

iii) Cost-efficiency

iv) Colorless architecture
- Stable, accurate DSP-based operation
- Non-disruptive to legacy ODN

GreenDroid: Exploring the Next Evolution in Smartphone Application Processors

Mobile application processors are soon to replace desktop processors as the focus of innovation in microprocessor technology. Already, these processors have largely caught up to their more power hungry cousins, supporting out-of-order execution and multicore processing. In the near future, the exponentially worsening problem of dark silicon (that cannot be used due to power leakage) is going to be the primary force that dictates the evolution of these designs. The natural evolution of mobile application processors is to use this dark silicon to create hundreds of automatically generated energy-saving cores, called Conservation(c) cores, which can reduce energy consumption by an order of magnitude.

The GreenDroid prototype is a demonstration vehicle that shows the widespread application of c-cores to a large code base: Android. C-cores will enable the conversion of dark silicon into energy savings and allow increased parallel execution under strict power budgets. The prototype uses c-cores to reduce energy consumption for key regions of the Android system, even if those regions have irregular control and unpredictable dependent memory accesses. C-cores make use of the selective depipelining technique to reduce the overhead of executing highly irregular code by minimizing registers and clock transitions. It is estimated that the prototype will reduce processor energy consumption by 91 percent for the code that c-cores target, and result in an overall savings of 7.4×.

Source: IEEE Communication Magazine, April 2011

References: There are many to be individually acknowledged, the primary ones are cited here

1. *FSAN (Full Service Access Network) Group, a global consortium of over 80 leading telecommunications service providers, testing labs and equipment manufacturers. The event took place during January 25-28, 2011 in Tokyo, Japan.*
2. *OFDM for Next Generation Optical Access Networks Neda Cvijetic NEC Laboratories America ECOC 2010 Access Workshop September 19, 2010*
3. *Next Generation Optical Access Networks: from TDM to WDM Ll. Gutierrez1, P. Garfias1, M. De Andrade1, C. Cervelló-Pastor1 and S. Sallent2 Technical University of Catalonia (UPC)1 and i2cat Foundation2 Spain*
4. *Next Generation Optical Access Network Using CWDM Technology Saba Al-RUBAYE1, Anwer AL-DULAIMI2, Hamed Al-RAWESHIDY2 Wireless Networks & Communications Centre, School of Engineering & Design, Brunel University, London, UK Email: 1sabaday17@yahoo.com; 2anwer.al-dulaimi@brunel.ac.uk Received July 20, 2009; revised August 29, 2009; accepted September 23, 2009*
5. *"Introducing WDM into Next-Generation Access Networks" ADVA Optical Networking, Germany*

Published by: Telecom Regulatory Authority of India
Editorial responsibility: TDRA Division
Contributions, comments and suggestions: tdra@trai.gov.in, tdra.trai@gmail.com