Optical and Wireless Technology Integrations for Next Generation Broadband Access Networks

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Presentation Outline

- Introductions
- Problem Domain and Motivations
- Integrations Schemes
- EPON MAC Protocol Implementations Using OPNET
- IPACT Algorithm Implementations Using OPNET (work in progress)
- Converged Scenario Implementation
- Proposed Scheduling Algorithm for Optical and Wireless Integrations Scheme
- Initial Results
- Using Bayesian Belief Network Theory (BBN) in Support of Low-Level DBA inside ONU Towards Uplink Fibre in EPON (work in progress)
- Future Work, Publications and Presentations
Introduction

✓ Broadband access solutions in rural area:
  ▪ Digital Subscriber Line (DSL), Cable Modem (CM) and T-1/E-1 or optical cables are either unreachable or too costly to extend (insufficient rural area broadband access solutions)
  ▪ World Wide Interoperability for Microwave Access (WiMAX): low-cost, wide coverage (fixed & mobile), QoS and mobility supports

✓ WiMAX backhaul technology (controversial issue):
  ▪ T-1/E-1, DSL and CM networks
  ▪ T-1/E-1: provide QoS and support up to 2 Mbps transmission rate but they are not scalable and cost-aware solution
  ▪ DSL can provide high speed access by using existing telephone line but the performance depends on distance (>5.5 km) from central office & access time

✓ Passive Optical Networks (promising candidate for WiMAX backhaul):
  ▪ Offer higher bandwidth for users located > 20 km of CO, can be upgraded to higher bit rate and/or additional wavelength easily, inexpensive solution
  ▪ Scalable solution to support the Smart Digital Economies of tomorrow by focusing on Affordability and Availability goals of Tomorrow’s Digital Economy
Introduction Con..

✓ PON’s major standards:
  ▪ EPON (IEEE 802.3ah) and GPON (ITU-T G.984)

✓ PON Media Access Technology:
  ▪ TDM, WDM and CDM

✓ EPON:
  ▪ Low-cost PTMP fibre infra with Ethernet
  ▪ OLT, 1:N passive splitter (split range: 16, 32 or 64) /combiner or AWG and number of ONUs

✓ EPON & APON & SPON:
  ▪ APON (ATM-based PON) and SPON (SONET-based PON)
  ▪ Ethernet: inexpensive tech, off the shelves (ubiquitous), interpretable with legacy equipment and supports QoS schemes

✓ EPON Protocols:
  ▪ Multi Point Control Protocol (MPCP) for TDM EPON (EPON MAC protocol has been implemented and published in OPNETWORK2010)
  ▪ MPCP extension for WDM EPON
  ▪ Interleave Polling with Adaptive Cycle Time (IPACT) as well-known and standard dynamic bandwidth allocation algorithm for EPON (IPACT implementation is in our work in progress using OPNET)
Wireless Technology Generations:

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Processor</th>
<th>Technologies</th>
<th>Generation</th>
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<tbody>
<tr>
<td></td>
<td>8086</td>
<td>AMPS, TACS, NMT</td>
<td>ANALOG, 1G</td>
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<tr>
<td></td>
<td>RISC</td>
<td>GSM, TDMA, CDMA</td>
<td>DIGITAL, 2G</td>
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<td></td>
<td></td>
<td>GPRS, EDGE, IS-95B</td>
<td>DIGITAL MULTIMEDIA, 2.5G</td>
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<tr>
<td></td>
<td></td>
<td>CDMA2000, W-CDMA, UMTS, HSDPA</td>
<td>MEDIA AND TV, 3G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MC-CDMA, WiMAX, W-OFDM</td>
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EPON Technology Generations:

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<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Downstream</td>
<td>1.25 Gbps</td>
<td>2.5 Gbps</td>
<td>10.31 Gbps</td>
</tr>
<tr>
<td>Upstream</td>
<td>1.25 Gbps</td>
<td>1.25 Gbps</td>
<td>1.25 Gbps</td>
</tr>
<tr>
<td>Maximum Coverage</td>
<td>20 km</td>
<td>20 km</td>
<td>20km</td>
</tr>
<tr>
<td>QoS and Traffic Management</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports other generations</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supporting IPV6</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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Problem Domain and Motivations

✓ TDM PON and WDM PON:
  ▪ TDM PON: the optical carrier (OC) is shared between number of ONUs timely so to avoid long delay the number of ONUs and SSs per ONU is limited (support 16 ONUs in 20km and 32 ONUs in 10 km)
  ▪ TDM needs to upgrade to WDM: higher bandwidth and more SS. Synchronization also adds extra complexity to TDM PON
  ▪ WDM supports multiple wavelengths over the same fibre

✓ Converged schemes:
  ▪ Two converged scenarios for hybrid optical and wireless integration have been implemented in which TDM EPON and WDM EPON have been both been considered

✓ Upstream scheduling algorithm:
  ▪ An upstream scheduling algorithm has been proposed which is under evaluation. This is the only module that defines which priority queue, for how long and in which order, accesses the upstream shared fibre when the time slot arrives from ONU on the correspondent BS.

✓ New Intelligent Algorithm for Burst Detection Inside ONU in EPON Scenario:
  ▪ We are also using Bayesian Belief Networks Theory (BBNs) as a burst detection tool in context of ONU low-level scheduler in EPON scenario.
Hybrid Optical and Wireless Integration Scheme (1)
Hybrid Optical and Wireless Integration Scheme (2)
Converged Module for Optical and Wireless Integrations

OLT (CO)

(1) OLT Auto-Discovery module

(2) Wavelength allocation module (using GATE msg. in MPCP extension)

Advanced ONU

(8) GATE generator

Advanced BS

(7) WiMAX PULLING module

(7) EPON REPORT generator

(9) WiMAX GATE processor

(10) WiMAX GRANT module

(11) Scheduler module (starts sending traffic to AD.BS)

(13) Scheduler Module (sending traffic to AD.ONU)

(12) QOS mapping module

Wi-Fi AP

(4) 802.11 REQUEST generator

(5) Classifier module

(11) Scheduler module (starts sending traffic to AD.BS)

(3) BW Reqs.

WLAN users

(4) 802.11 REQUEST generator

(13) Scheduler Module (sending traffic to AD.ONU)

(12) QOS mapping module

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EPON MAC Protocol (MPCP) Implementations Using OPNET
Presented and Published in OPNETWORK2010
EPON MAC Protocol (MPCP) Implementations Using OPNET

OLT node model

ONU node model

OLT process model

ONU process model
Implementation and Comparison of the Dynamic and Static BA Algorithms in EPON (SDBA and DDBA) (Timing Regime)

\[
\text{grant}_{n} = \text{grant}_{n-1} + \text{Gap} + \text{RTT}_{i}
\]

\[
\text{grant}_{n} = \text{grant}_{n} + \text{grant}_{\text{length}}
\]

Average queuing size for AF, EF and BE in DBA

Average queuing delay SBA vs. DBA for EF
Interleave Polling with Adaptive Cycle Time (IPACT) Algorithm (Implementation Using OPNET (in progress))

- IPACT is an standard and dynamic bandwidth allocation algorithm for EPON (higher bandwidth utilization)
- Similar to hub polling in which next ONU is polled before the transmission of the previous one has arrived.
Converged Scenario Implementations Using OPNET
Upstream Scheduling Algorithms

✓ Defines: which queue, for how long and in which order should send data when the allocated time slot arrives from ONU.
✓ Avoid collision.
✓ Queue inside BS: UGS for voice, rtPS for Video and BE for ftp service classes.
  - Priority Queue (PQ)
  - Custom Queue (CQ) [14.000, 8.000 and 2.000 BC for UGS, rtPS and BE, respectively]
  - Custom Queue with Low Latency Queue (CQ-LLQ) [BE gets the LLQ attribute]
  - Weight Fair Queue (WFQ) [60, 30 and 1.0 for UGS, rtPS and BE, respectively]
  - Weight Fair Queue with Low Latency Queue (WFQ-LLQ) [BE gets the LLQ attribute]
  - Modified Deficit Round Robin (MDRR) [50%, 30% and 20% for UGS, rtPS and BE, respectively]

Our work is here
Proposed Scheduling Algorithm work in progress

Table 1. Parameters for Scheduling Algorithm

<table>
<thead>
<tr>
<th>UGS</th>
<th>rTPS</th>
<th>BE</th>
</tr>
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<tbody>
<tr>
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</tr>
</tbody>
</table>

When the allocated bandwidth from ONU arrives in the format of time slot:
1. Capture the time slot
2. Reload the guaranteed bandwidth for three different priority queues
3. Calculate the byte count (BC) for each priority queue with regard to the guaranteed bandwidth
   \[ BC_i = (K_i \times 512) + MTU \]  
4. Reload the last reported queue length for each priority queue
5. Compare the last reported queue length with guaranteed byte counts for each priority queue
6. Condition one:
   \[ Q_{i}^{length} < BC_i \]  
   \[ B_{i}^{grt} = Q_{i}^{length} \]  
   \[ B_{excess}^{total} += BC_i - Q_{i}^{length} \]  
7. In this condition queue length is less than the guaranteed byte count. In this case scheduler decides to grant byte counts equal to the queue length and the extra byte counts is saved for later allocations
8. Condition two:
   \[ Q_{i}^{length} = BC_i \]  
   \[ B_{i}^{grt} = BC_i \]  
9. In this condition the reported queue length is equal to the guaranteed byte counts. In this case scheduler decides to grant byte counts equal to the guaranteed byte counts and there is now extra byte counts to save
10. Condition two:
    \[ Q_{i}^{length} > BC_i \]  
    \[ B_{i}^{grt} = BC_i + K_i \times B_{excess}^{total} \]  
11. In this condition the reported queue length is more than the guaranteed byte counts. In this case scheduler decides to grant byte counts equal to the guaranteed byte counts and a portion of the extra byte counts collected in condition one.
Initial Results

- UGS average ETE delay (sec) over CQ and PQ scheduling
- BE average ETE delay (sec) over different scheduling techniques
- rtPS average ETE delay (sec) over CQ and CQ_LLQ scheduling
- UGS average ETE delay (sec) over different scheduling techniques
Using BBN in Support of DBA in EPON (Proposal and Initial work have been accepted to Present and Publish in ICWOC2011)

✓ Problem definitions:
Bayesian Belief Networks (BBNs) theory has been proposed as the burst detection tool inside Optical Network Unit (ONU) in support of bandwidth request towards up-link fibre in EPON scenario. In BBNs problem is structured as a set of variables by considering the probabilistic relation between one another. Bursty traffic is data flow which may have negative effect on the ONU buffer such as data flow which results in overflowing the buffer, increasing the queuing delay, increasing the queue length, etc. It is referring to any situation in which a source is transmitting data rapidly which may degrade the QoS if it does not handle efficiently.
BBN in context of the scheduler inside ONU

- Subscribers' traffic from EPON
- Classifier
  - EF
  - AF
  - BE
- Priority Queues in EPON
- Allocated Time slot from OLT
- Upstream Shared Bandwidth towards OLT
- BBN model
- Background information
- Burst?
- Traffic_in
- Burst detection model
  - Packet_drop
  - Queuing_delay
  - Queue_length
  - Traffic_out
Flowchart for ONU Operation Using BBN Technique

EPON SIMULATION PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of ONU</td>
<td>16</td>
</tr>
<tr>
<td>Distance between Splitter and ONU</td>
<td>5 km</td>
</tr>
<tr>
<td>Distance between OLT and ONU</td>
<td>20 km</td>
</tr>
<tr>
<td>Packet size</td>
<td>Exponential (1024 byte)</td>
</tr>
<tr>
<td>Traffic type</td>
<td>Bursty source</td>
</tr>
<tr>
<td>Packet Interarrival time</td>
<td>Exponential (1.0)</td>
</tr>
<tr>
<td>ON time for bursty sources</td>
<td>Exponential (90.0)</td>
</tr>
<tr>
<td>OFF time for bursty sources</td>
<td>Exponential (10.0)</td>
</tr>
<tr>
<td>Total number of sub-nets per ONU</td>
<td>3</td>
</tr>
<tr>
<td>Total number of buffer per ONU</td>
<td>3</td>
</tr>
<tr>
<td>Supported service classes</td>
<td>3 (EF, AF and BE)</td>
</tr>
<tr>
<td>Uplink fiber speed to OLT</td>
<td>1 Gbps</td>
</tr>
<tr>
<td>Buffer size</td>
<td>8 Mb</td>
</tr>
<tr>
<td>Max bandwidth per ONU</td>
<td>65 Mbps</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>2ms</td>
</tr>
<tr>
<td>Guard time</td>
<td>1 µs</td>
</tr>
</tbody>
</table>

Traffic sent by bursty source over 10 sec to 80 sec ON time
Work in Progress and Future Work

- Improve the performance of the proposed scheduling algorithm for optical and wireless converged scenario which works inside base station.

- Implementation of Interleaved Polling with Adaptive Cycle Time (IPACT) as well-known and standard dynamic algorithm in our previously implemented EPON scenario which is under progress.

- Evaluating the proposed BBN-based burst detection model.
List of Presentations and Publications

-N. Moradpoor, G. Parr, S. McClean, B. Scotney and G. Owusu, "Hybrid Optical and Wireless Technology Integrations for Next Generation Broadband Access Networks", 6th IFIP/IEEE International Workshop on Broadband Convergence Networks (BcN 2011), Accepted to present and publish conference information at:
http://www.ieee-im.org/cfpworkshops.html

-N. Moradpoor, G. Parr, S. McClean, B. Scotney and G. Owusu, "Using Bayesian Belief Networks for Burst Detection in Ethernet Passive Optical Networks", 2011 International Conference on Wireless and Optical Communications (ICWOC 2011), Accepted to present and publish conference information at:
http://www.icwoc.org/

-N. Moradpoor, G. Parr, S. McClean, B. Scotney and K. Sivalingam (IIT Madras), "Simulation and Performance Evaluation of Bandwidth Allocation Algorithms for Ethernet Passive Optical Networks (EPONs)", OPNET's annual technology conference (OPNETWORK2010), Accepted to present and publish conference information at:

-N. Moradpoor, G. Parr, S. McClean, B. Scotney and G. Owusu (BT Adastral Park), "Present around the World: IET Young Professionals' Flagship Worldwide Presentation Competition", Queen's University of Belfast, November 2009, presented information link at:
http://www.theiet.org

http://www.cms.livjm.ac.uk/pgnet2009/Proceedings/