Lecture #4

Wireless Network Convergence and Fixed Mobile Convergence

Dr. Kun Yang
University of Essex, Colchester, UK

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Agenda

- Network Convergence among Wireless Networks
- Network Convergence between Fixed and Mobile Networks
- Summary, Q&A
Wireless Access Networks

- There are many different types of wireless access networks.
- There will be no perfect wireless system in terms of various factors such as mobility, capacity, coverage, and cost.
- Instead, these networks, each with its unique features, will co-exist.

- Technologies that enable users to seamlessly and easily use these networks are needed.

Wireless Mobile Internet – driven from mobile devices

- 2B cell phones vs. 500M Internet-connected PC in 2005
- 400M cell phones with Internet capability, rising rapidly
- Wireless devices will be more portable, more intelligent, more functional and with multi-radio access capacity.

There is a historic shift from PC’s to mobile devices for Internet access.

Mobile applications get more complicated.
Wireless Convergence: Loosely Coupled

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Heterogeneous Wireless for e-Health @ UEssex

- “Always-on” lifeline using media-independent handover (MIH) across heterogeneous wireless networks (standardised within IEEE802.21)
- Video conferencing/VOIP to patient from home (also while mobile, but less practical!)

- Fall detector
- Heart Monitor
- Blood Oxygen
- Blood Glucose
- Bluetooth (100m range)
- WiMAX
- WiFi
- GPRS
- Blood Glucose Sensors
- MIH (802.21)
- HSDPA (3G)
- Processor
- Linux low power miniPC
- Storage
- Router
- GPS
- WIMAX
- WiFi
- GPRS
- HSDPA (3G)

- LCD Monitor
- Camera, mic, speaker
- VoIP/Video Conference
- Ethernet (fixed broadband connection)
- Media Independent Gateway (MIG)
- Mobile Version
iDorm – Digital Lifestyle Environments

iDorm1 (development environment)
- Single student bed-sit (work, sleep etc)

iSpace (evaluation environment)
- Test-bed for ambient intelligent and pervasive computing in a domestic setting (Full sized 2 bedroom apartment)
- Sensor, actuator, computer and network rich environment to enable open-ended R&D
- £250,000 in IT related aspects (+£100,000 energy equipment)
- Capable of supporting evaluations with long-term occupants

For further information, contact Prof Vic Callaghan (vic@essex.ac.uk)

A Closely-coupled HWN: Motivation

Current cellular systems are limited in flexibilities in that cellular architectures are fixed and bandwidth allocation cannot dynamically adapt to instant network change.

As a result, some cells could be congested because of temporary events, such as traffic accidents and sports events.

Proposal: introduce MANET over cellular networks to divert traffic.

- Existing work:
  - iCAR: diversion station has only cellular interface
  - UCAN: high-date rate, within a cell
Physical Characteristics of the HWN system

- BS: no change from the current UMTS BS
- TDS: with both cellular and ad hoc interfaces, deployed close to the borders of a cell
- MH: with only A-interface, C-interface, or both interfaces.

QoS: QoS Mapping

<table>
<thead>
<tr>
<th>IEEE802.11e priority</th>
<th>UMTS traffic class</th>
<th>IP delay class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (hig/Net)</td>
<td>Conversational (with stringent and low delay demand, e.g., voice or video telephony, or video streaming)</td>
<td>10 ms</td>
</tr>
<tr>
<td>1</td>
<td>Streaming (not too sensitive to delay but no delay variation, e.g., video streaming)</td>
<td>50 ms</td>
</tr>
<tr>
<td>2 (interactive)</td>
<td>Interactive (with soft delay constraints, e.g., Web browsing)</td>
<td>100 ms</td>
</tr>
<tr>
<td>3 (low/Net)</td>
<td>Background (with no-time constraints, e.g., background file downloading)</td>
<td>No delay bound</td>
</tr>
</tbody>
</table>

Table 1. QoS parameter mappings.
Adaptive Routing

Source Selection
- MH initiates a request but blocked.
- MHj releases channel; MHj uses the channel; YES
- MHj empty? NO
- MHj = MHs; MHs = MHj;

Destination Selection
- Is there a TDS next to MHs?
- Source Selection Procedure: find a MHj in the same cell as MHs.
- MHj empty? NO
- MHj releases channel; MHj uses the channel; YES
- MHj empty? NO
- MHj = MHs; MHs = MHj;

Route Selection
- Route Discovery Procedure: discover route R = {rk | k = 1, ..., |R|}.
- Is R empty? NO
- MHj empty? YES
- Failure

Route Discovery Procedure: transmit data from MHs using route r.
- MHj releases channel; MHj uses the channel; YES
- MHj empty? NO
- MHj = MHs; MHs = MHj;

Not needed in normal routing

Source Selection
- Destination Selection
- Route discovery & selection

Evaluation

The structure of a single cell

The whole network environment

The structure of a single cell
Further Integration with DVB

DVB-H: Digital Video Broadcast-Handheld

- Three types of nets
- Unicast+broadcast
- Uplink for DVB via cellular net.

It utilizes a policy-based mngt (PBM) approach in combination with fuzzy control theory, aiming to maximize the overall effectiveness, flexibility, and robustness of the network.

Overall architecture

WLAN overlays UMTS. UMTS and DVB-H networks operate separately but connected via a pair of signalling gateways.

How the three types of networks collaborate to fulfill a service as coordinated by the USG.
Agenda

- Network Convergence among Wireless Networks
- Network Convergence between Fixed and Mobile Networks: EPON+WiMAX
- Summary, Q&A


Background

- IEEE 802.16 provides wireless broadband access with high bandwidth capacity, large network coverage, strong QoS support.
- But how to backhaul its traffic? -> EPON (Ethernet Passive Optical Network), a point-to-multipoint optical access network technology.
- The most popular EPON topology is tree-based architecture where transmission occurs between an optical line terminal (OLT) and multiple optical network units (ONUs).
  - The OLT is usually connected to the core networks whereas each ONU locates at either curb (thus the so called fiber-to-the-curb or FTTC), within a residential building (i.e., fiber-to-the-building or FTTB), or even to the home (i.e., fiber-to-the-home or FTTH).
  - Of course, an ONU can be connected to an IEEE 802.16 base station (BS).
We assume that an EPON ONU is integrated with an 802.16 BS into a converged box called **Virtual ONU-BS (VOB)**.
- We call it “virtual” because there is not such an integrated box physically.

**Why this Convergence?**

- Firstly, most 802.16 BSs are equipped with Ethernet interface as such can be easily connected to EPON.
- Secondly, both technologies share many similarities in terms of bandwidth request/allocation and QoS supporting mechanisms.
- Thirdly, EPON and 802.16 also complement each other in that the convergence of two has the potential to combine the bandwidth advantage of optical networks with the mobility feature of wireless communications.
- Furthermore, this integration enables the design of joint bandwidth allocation/reservation, connection admission control and transmission scheduling schemes.
  - These collaborative schemes are more likely to provide a close-to-optimal solution to system’s overall resource management, including both wired optical resources and wireless radio resources.
  - In return, a better support of end-to-end QoS guarantee and improvement of overall system performances such as throughput and delay can be expected.
  - But how to design such schemes is still an open and challenging issue!
  - We endeavor to make a first-step attempt towards this challenge by focusing on bandwidth allocation.
A bit of state-of-the-art on FMC

- Application Layer: IMS (IP Multimedia Sub-system)/ SIP (Session Initiation Protocol) -> loads of work
- Physical Layer: Radio over Fibre (RoF) -> tons of work
- MAC Layer
  - C. Qiao. et al. appears to consider FMC in a layer other than physical layer or application layer. However, this seminal work does not reflect too much the flavor of 802.16 networks. IEEE OFC March 2006 – seminal work
  - Shen et al. recently summarize the architecture issues arising in the integration of EPON and 802.16, but not concrete algorithm details presented. Ref. IEEE ComMag, Aug. 2007 – work at roughly the same timeline as ours.
- Our work endeavors to design a QoS-aware dynamic bandwidth allocation (DBA) scheme at the MAC layer for a converged network of EPON and 802.16.

Technical Focus

- Firstly, to propose converged network architecture of EPON and 802.16 (especially the concept of VOB) and identify the unique research issues as a result of this convergence.
- Secondly, to investigate a DBA scheme that is specifically designed for the WEN networks. This DBA scheme takes into consideration the specific features of the converged network to enable:
  - (1) a smooth data transmission across optical and wireless networks,
  - (2) an end-to-end differentiated service to user traffics of diverse CoS (Class of Service) requirements. Here the end-to-end means from a connection originated from an 802.16 SS to the OLT.
    - This QoS-aware DBA scheme shall ensure certain fairness under network traffic saturation condition along both station dimension and CoS dimension.
    - CoS fairness specifically means that the low-priority traffic (such as best effort traffic) shall not be significantly disadvantaged under network saturation condition.
- The proposed DBA scheme, called WE-DBA for WiMAX-EPON DBA
A bit practical work first …

Feasibility Study: Experiments


The **GPON equipment** used: one Ericsson EDA 1500 (OLT) and three T050G ONU's. **IEEE 802.16**: one Airspan MicroMAXB BS (AS.MAX MicroMAX-SOC) and three SSs (AS.MAX ProST).
GPON and 802.16 Upstream Packet Classification and QoS Mapping

SS Queues

GPON 802.16

UGS

ertPS

rtPS

nrtPS

BE

SS Classifier

ONU Scheduler

BS

To ONU

OLT

802.16

Services

Lowest-Cost-First Mapping Algorithm

Dynamic Bandwidth Control

VOD Server

Service Manager

Control Bridge

GPON

OLT

BS

VOD Client

1. VOD service request

2. service granted/rejected

3. Invoke Control API to provide just-enough BW

4. Resize the CIR of the service flow

5. Resize the max. BW allocated for the T-CONT

6. Inform VOD server to provide service to the client

7. VOD service begins

8. VOD service ends

9. Invoke Control API to release BW

10. Release allocated BW

11. Release allocated BW

b. An Example of Packet Classification in SS Classifier

c. An Example of Packet Classification in ONU Classifier

802.16 User Priority

7

6

5

4

3

2

1

0

DSCP

EF

AF4x

AF3x

AF2x

AF1x

BE

Classified by other parameters (such as source/destination MAC address, VLAN ID, IP protocol, etc.)
Some results

![Graphs showing channel utilization, delivery cost, and delivery ratio with and without control bridge.

A bit theoretical work …
**Virtual ONU-BS (VOB) Box**

**Hardware Layout**

**Logical Architecture**

**Bandwidth Request & Grant**

- The VOB queues are presented as virtual queues by dashed lines because these queues represent the bandwidth requested instead of the real data.
- EPON: Multi-Point Control Protocol (MPCP); IEEE 802.16 has similar mechanism and procedure.
- These standardised mechanisms have defined the precise format for bandwidth request and grant messages as well as their processing. However, no DBA algorithm is specified.
- Note that VOBs employ MPCP for bandwidth request and the 802.16 mechanism for bandwidth grant.
Refer to the attached paper for technical details and discussion.
**Algorithm 1: VOB-DBA algorithm on VOB i.**

1. get $B_{x}^{req}$ from $x \in \{\text{all SSs}\}$ and get $B_{j}^{req}, j = 1, \ldots, 3$.
2. get $B_{i}^{p}$ from the OLT.
3. if $D_{i}^{p} \geq \sum_{j=1}^{3} B_{j}^{req}$ then
4. $B_{i}^{p} = B_{j}^{req}$
5. $B_{x,j}^{p} = B_{x,j}^{req}, j = 1, \ldots, 3$
6. else
7. $B_{x}^{sel} = B_{i}^{p} - \sum_{j=1}^{n_{p}} B_{x,j}^{req}$
8. $B_{x}^{sel} = B_{BE}^{avg} \times n_{SS}$
9. $B_{i}^{p} = B_{x}^{sel} - B_{x}^{sel}$
10. if $B_{x}^{sel} > \sum_{j=1}^{n_{p}} B_{x,j}^{req}$ then
11. $B_{i}^{p} = \sum_{x=1}^{n_{p}} B_{x}^{p}$
12. $B_{x}^{p} = B_{x}^{BE} + (B_{x}^{sel} - \sum_{x=1}^{n_{p}} B_{x}^{req}) / n_{p3}$
13. else
14. $B_{x}^{p} = B_{x}^{p}$
15. $B_{x}^{p} = B_{x}^{sel} / n_{p2}$
16. endif

$v_{p1}, v_{p2}, v_{p3}$: numbers of SSs that have P1, P2, P3 traffics, respectively.

$B_{x}^{p1}, B_{x}^{p2}, B_{x}^{p3}$: the amount of granted bandwidth to P1, P2, P3 traffics on SS $x$, respectively.

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**DBA at VOB**

$$B_{BE}^{min} = \alpha \times B_{BE}^{avg}$$

$$B_{BE,p}^{avg} = \frac{\text{Traffic}_{BE,p}}{2}$$

$$B_{BE,p}^{avg} = (B_{BE}^{avg} + \text{Traffic}_{BE,p}) / 2$$

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**Evaluation Design**

- **Benchmarks:**
  - **DBA1:** both the OLT and VOBs statically allocate bandwidth (equal share) to its client stations.
  - **DBA2:** EPON static whereas 802.16 dynamic (the other way round is less common)

- **Test design:**
  - To evaluate against benchmark to show the benefit of dynamic
    - in terms of throughput and delay
  - To evaluate itself under different conditions.
    - In terms of throughput and delay under different serving cycles, types of services, channel utilization, and BE windows
Overall Throughput of WEN under different DBA schemes

Average Delay of WEN under different DBA schemes
**Throughput under different Serving Cycles**

![Throughput Graph]

**Delay under different Serving Cycles**

![Delay Graph]
Conclusions

- PON+802.16 at MAC appears to be beneficial though just some very limited preliminary work being carried out.
- However, this is a massive research topic and much more effort is needed.
  - Other topics such as scheduling and admission control, a comparative study on the performance differences between a centralized control mechanism (carried out by the OLT) and a cascading decision making strategy.
  - Investigation into the effect of mobility on network performance.
  - Long-term work includes research into a fully unified hardware VOB.
Dr Kun Yang  
School of Computer Science & Elec. Eng. (CSEE),  
University of Essex, Wivenhoe Park, Colchester,  
CO4 3SQ, UK  
- Email: kunyang@essex.ac.uk  
- http://privatewww.essex.ac.uk/~kunyang/