Fiber-Wireless (FiWi) Access Networks

Martin Maier, PhD
Associate Professor
Outline

- Motivation
- FiWi access networks: a new research area
- State-of-the-art FiWi networks
- Testbeds & lessons learned
- Future challenges & imperatives
- Conclusions
FTTx

• At present, there is a strong worldwide push toward bringing optical fiber closer to homes & businesses => FTTx networks
  ➢ x denotes discontinuity between optical fiber & some other transmission medium, e.g., copper
    ✓ HFC
    ✓ DSL
• From a capacity point of view, there is no techno-economic need & justification to replace hybrid fiber-twisted pair based DSL networks with all-optical solutions
  ➢ Copper-PON (CuPON) multidropping DSL architecture
    ✓ 50 Gb/s of shared bandwidth in each direction on existing twisted pair of copper telephone lines
    ✓ Much higher data rates than state-of-the-art IEEE 802.3ah/v EPON & ITU-T G.984 GPON
Recent FTTx trends

- Optical fiber is expected to eventually become medium of choice in wired first/last mile access networks
  - **Greenfield deployments**
    - In most of today’s greenfield deployments fiber rather than copper cables are installed for broadband access
  - **Brownfield deployments**
    - Important to reduce installation costs, e.g., NTT’s do-it-yourself (DIY) installation of low-cost FTTH ONUs
  - **Fiber to the Display (FTTD)**
    - Plastic optical fiber (POF) directly connected to large flat panel display => telemedicine or emerging digital cinema standard
FTTH

• Fiber-to-the-home (FTTH) networks are expected to become next major success story for optical communications systems
• FTTH connections are currently experiencing double-digit or even higher growth rates
  ➢ For instance, in the U.S. the annual growth rate was 112% between Sept. 2006 to Sept. 2007 *
• Typically, realized as passive optical networks (PONs)
  ➢ Benefits
    ✓ Reliability, longevity, maintenance costs, and reach (DSL???)
    ✓ Transparency & future-proofness
    ✓ Can add value of U.S. $4,000-15,000 to selling price of home *

NG-PONs

- EPON & GPON are expected to coexist for foreseeable future as they evolve into Next-Generation PONs (NG-PONs)
  - High-speed TDM PON, e.g., IEEE 802.3av 10 Gb/s EPON
  - WDM PON
  - Long-reach PON
  - Migration toward integrated optical access-metro networks
  - Optical-wireless integration
    - Convergence of optical access networks with their wireless counterparts
    - Optical & wireless technologies can be thought of as quite complementary
    - Future broadband access networks will be bimodal capitalizing on respective strengths => fiber-wireless (FiWi) networks
FiWi networks: a new research area

- FiWi networks are realized by integrating wireless access technologies, e.g., cellular, WiMAX, and WiFi, with optical access technologies, e.g., EPON, GbE, and RPR

- Related research topics
  - Fixed mobile convergence (FMC) ✗
    - According to ETSI, FMC seamlessly offers consistent services via fixed or mobile access to fixed or mobile, public or private, networks, independently of access technique
    - Can be done at different levels, e.g., business or services provisioning level
    - Does not necessarily imply physical convergence of networks
  - Fixed mobile integration (FMI) ✔
    - Convergence at network facilities level using the same physical network infrastructure with common transmission and switching systems
FiWi networks: a new research area

• Related research topics (cont’d)

  ➢ Optical wireless integration (OWI) ✔
    ✓ OWI aims at integrating PONs with emerging wireless access technologies, most notably WiMAX
      • Increased capacity of wireless access networks
      • Reduced access point complexity through centralized management

  ➢ Optical wireless (OW) communications ✗
    ✓ Designed in the 1960’s, well before development of optical fiber communications
    ✓ Free-space OW links and networks
      • Operate at much higher carrier frequencies than current RF wireless systems, e.g., WiMAX, WiFi, and UWB
      • Do not involve any wired (fiber) infrastructure
      • May be deployed as temporary wireless backhaul
FiWi networks: a new research area

- Related research topics (cont’d)
  - Radio-over-Fiber (RoF) networks ✔
    - Pros
      - RFs are carried over optical fiber between CO and RAUs supporting a variety of wireless applications
      - Optical fiber range of up to 50 km demonstrated
    - Cons
      - May have detrimental impact on the performance of wireless MAC protocols by exceeding certain timeouts, e.g., ACK timeout of widely deployed DCF in IEEE 802.11a/b/g WLANs
      - Optical fiber can be deployed in WLAN-based RoF networks only up to a maximum length, typically below 2 km !!!
  - Radio-and-Fiber (R&F) networks ✔
    - Avoid limitations of RoF networks via MAC protocol translation
    - Control access to optical and wireless media separately
FiWi networks: a new research area

- FiWi networks may deploy both RoF and R&F technologies
  - R&F networks
    - Well suited for distributed wireless MAC protocols, e.g., DCF
  - RoF networks
    - Well suited for wireless MAC protocols that deploy centralized polling & scheduling, e.g., WiMAX

- FiWi networking research focuses on
  - PHY layer
    - Optical RF generation exploiting fiber nonlinearities
    - Advanced (re)modulation techniques
  - MAC layer
    - Performance-enhancing MAC mechanisms & hybrid MAC protocols
    - Integrated path selection algorithms
    - Advanced resilience techniques
State-of-the-art FiWi networks

Recent survey of state-of-the-art FiWi networks:

N. Ghazisaidi, M. Maier, and C. M. Assi
RoF network: multiservice access network

- FTTH baseband & RF signal RoF network
R&F network: SuperMAN

- Optical-wireless interface between RPR and WiMAX
Testbeds & lessons learned

- **Georgia Tech RoF testbed**
  - Demonstration of 270 Mb/s SD & 1.485 Gb/s HD video streaming
  - Experimental results show very good BER performance of received video signals
Testbeds & lessons learned

• UC Davis R&F testbed
  - Concatination of 2 EPONs & 802.11g WLAN-based WMN
  - Optical protection provided using full PON duplication
  - Quality of video sharply deteriorates for increasing number of wireless hops (blank screen after 4 hops !!!)
Future challenges & imperatives

- Development of layer-2 protocols & algorithms
  - Integrated channel assignment & bandwidth allocation
    - Load balancing
    - Reconfiguration
  - Integrated path selection
    - Logical topology design of reconfigurable optical backhaul
    - Decrease of handovers for high-speed mobile subscribers
  - Optical burst assembly & wireless frame aggregation
    - HT-WLAN (IEEE 802.11n) frame aggregation schemes (A-MPDU, A-MSDU) for EPON
    - Hierarchical optical burst assembly/wireless frame aggregation schemes
  - Flow & congestion control
    - Mitigation of bandwidth disparity at optical-wireless interface, buffer overflows, and packet retransmissions
Conclusions

• A plethora of enabling RoF & R&F technologies are emerging to build bimodal FiWi broadband access networks

• FiWi networks form powerful future-proof platform that provides a number of advantages

• Among others, FiWi networks provide the following benefits
  ➢ Introducing fiber into wireless access networks helps relieve emerging bandwidth bottlenecks generated by new applications, e.g., iPhone
  ➢ Providing wired & wireless services over same infrastructure helps consolidate optical and wireless access networks which traditionally have been operated separately from each other => major cost savings

• FiWi layer-2 networking research has begun only recently
  ➢ Crucial to unleash full potential of FiWi networks (hint: see 802.11n)
Fiber-Wireless (FiWi) Broadband Access Networks

Motivation

Future broadband access networks will be bimodal, capitalizing on the respective strengths of both optical and wireless technologies and smartly merging them in order to realize future-proof Fiber-Wireless (FiWi) networks that strengthen our information society while avoiding its digital divide. By combining the capacity of optical fiber networks with the ubiquity and mobility of wireless networks, FiWi networks form a powerful platform for the support and creation of emerging as well as future unforeseen applications and services, e.g., telepresence. FiWi networks hold great promise to change the way we live and work by replacing commuting with teleworking. This not only provides more time for professional and personal activities for corporate and our own personal benefit, but also helps reduce fuel consumption and protect the environment, issues that are becoming increasingly important in our lives.

Research Direction

The proposed research direction includes the following FiWi broadband access network classifications:

Radio-and-Fiber (R&F)
Protocol translation might be done at the interface of optical and wireless segments by an appropriate optical-wireless device, such as Optical Network Unit – Base Station (ONU-BS), or at the optical part, e.g., by an Optical Line Terminal (OLT), in a Passive Optical Network (PON).

For further information visit www.zeitgeistlab.ca