Fiber-Wireless (FiWi) Access Networks

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Reference:

N. Ghazisaidi, M. Martin, and C. Assi, "Fiber-Wireless (FiWi) Access Networks: A Survey," IEEE Communications Magazine, pp. 160-167, Feb. 2009.

Outlines

- Motivation.
- Wireless Access Networks.
- Optical Access Networks.
- FiWi Networks.
- Future Challenges.

Motivation

- Internet and communication networks ultimate goal:

  "Provide access to information when we need it, where we need it, and in whatever format we need it in"

Wireless vs. Fiber Technologies

- Fiber tech.

  - Does not go everywhere.

  - Provides huge amount of bandwidth.

- Wireless tech.

  - Goes almost everywhere.

  - Has bandwidth limitations.

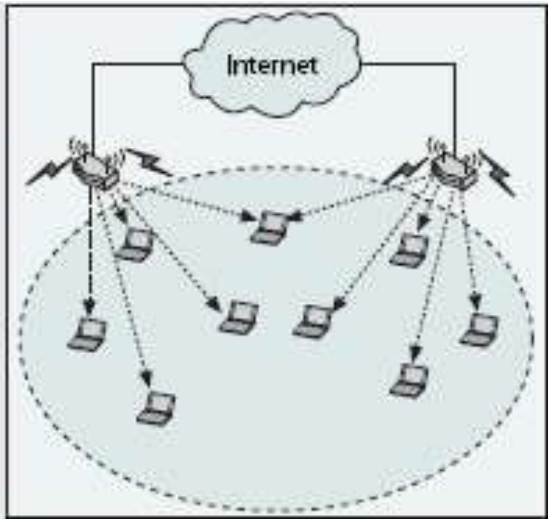
Fiber-Wireless (FiWi)

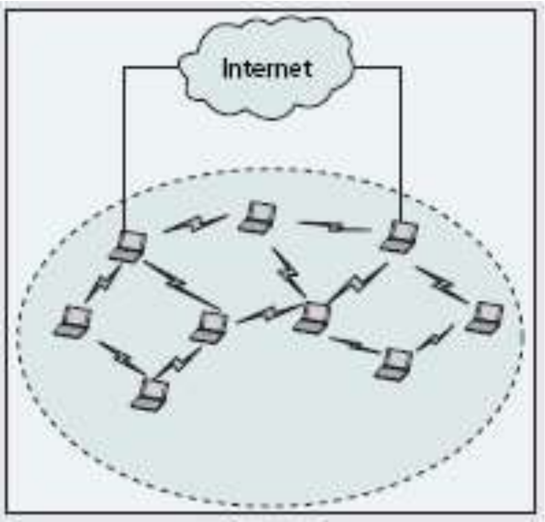
- FiWi is a hybrid fiber-wireless access network.
- FiWi merges the respective strengths of optical and wireless technologies and converges them seamlessly.
  - it combines the capacity of fiber networks with the mobility and reachability of wireless networks.
- FiWi forms a powerful platform for future services and applications.
- FiWi is a promising technology to change the way we live and work.
  - by replacing commuting with teleworking (reduces fuel consumption and protects the environment).
- FiWi networks provide new powerful access network solutions that satisfy the users' future demands.

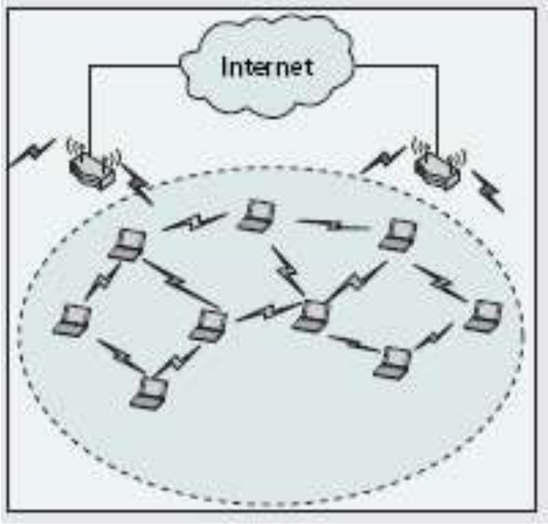
Wireless Access Network

- Cost-efficient and flexible wireless Internet access.
- WMN employs multi-hop comm. to forward traffic and route to/from wired network through gateways.
- WMN provides flexibility, increases reliability, and improves performance compared to Ad-hoc networks.

Wireless Access Network







Wireless Access Network

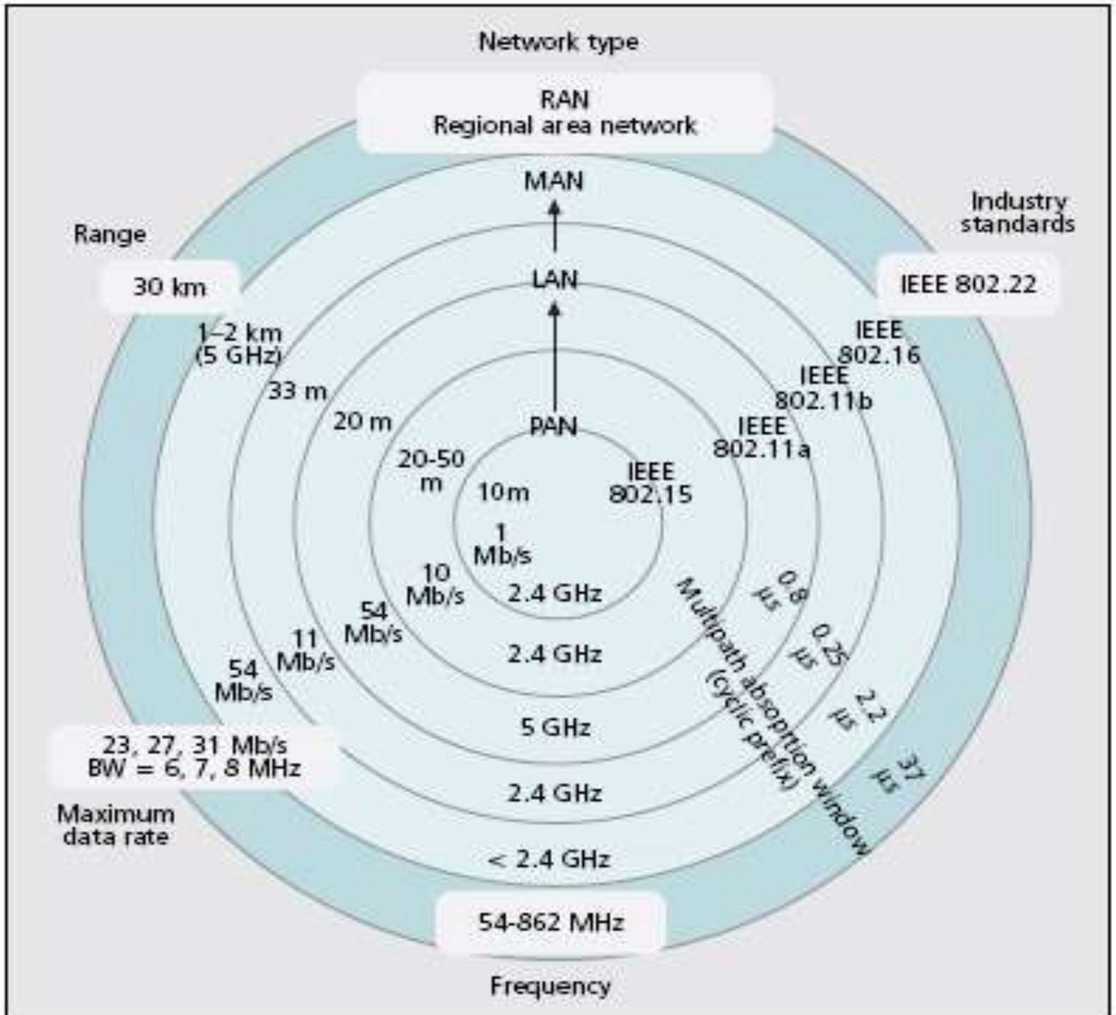
- Enabling technology (requirement to optimize WMN performance),

  - PHY layer: smart antenna, MIMO, multi-channel interface system, enabling wireless Gigabit transmission (MIMO + OFDM), etc.

  - MAC protocol: improve CSMA/CA bandwidth efficiency, (WiFi) WLAN, WiMAX,

  - Routing protocol: ETX, ETT, WCETT, etc.

Wireless Access Network



Ultra high bandwidth standard 802.16m (1Gbps).

Reference: C. R. ***Stevenson***, ***G. Chouinard, Z. Lei, W. Hu, S. J. Shellhammer, W. Caldwell,*** **"IEEE 802.22: The First Cognitive Radio Wireless Regional Area Network Standard," IEEE Comm. Mag. pp. 130-138, Jan. 2009.**

Optical Access Network

- Offers a total bandwidth of 25000 GHz.
- Uses low complexity, and power consumption electronic equipments.
- Provide optical transparency against modulation format, bit rate, and protocol.
- FTTX network:

  - opens up the first\last mile bandwidth bottleneck between BW-hungry end users and high-speed backbone.

  - supports a wide range of services and applications (e.g., HDTV, P2P, Video on demand, video file sharing, online games, telecommunicating).

Optical Access Network

- PON:

  - A TDM single channel system.

  - Fiber infrastructure carries a single (upstream\downstream) wavelength channel.

  - Widely deployed.

  - cost-efficient, low attenuation, huge bandwidth, and longevity.

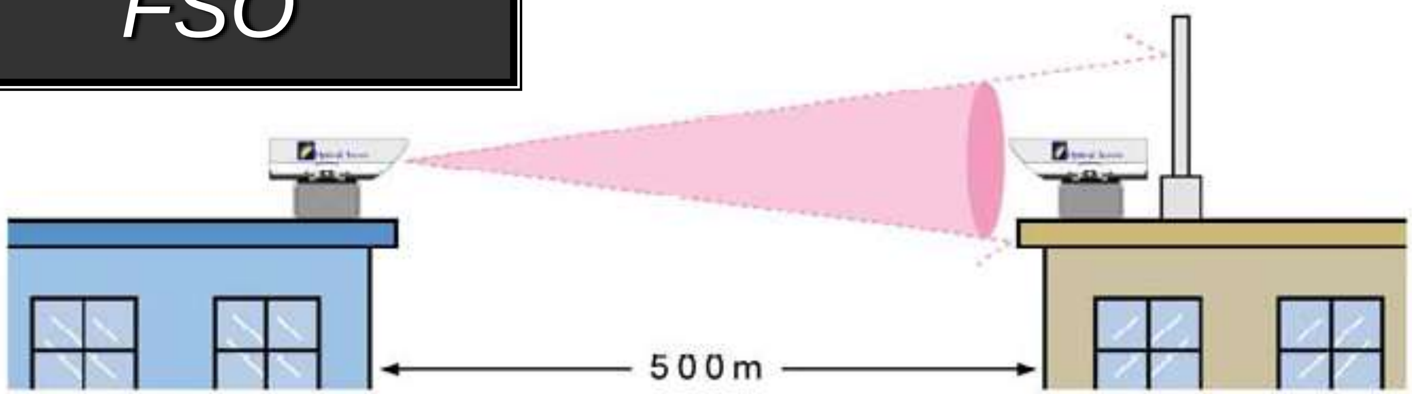
Optical Access Network

- EPON (802.3ah) with a symmetric line rate of 1.25 Gbps.
- EPON (802.3av) is a 10Gbps EPON.
- GPON (ITU-T standard G.984) with upstream line rate of 1.244 Gbps and downstream line rate of 2.488 Gbps
- GPON offers strong Operation, Administration, Maintenance, and Provisioning (OAMP) capabilities and security for downstream by encryption.
- EPON aims to converge the PON low cost equipment and the simplicity of Ethernet. However, EPON has security issues and no OAMP specifications.
- Generally, EPON is expected to become the norm in the future.

FiWi Network

FiWi Network

- R&F tech.
  - FSO
- RoF tech.



Free Space Optical (FSO)

100 Mbps GigE, Minneapolis, MN

1km GigE, Belfast, Ireland

1500m GigE, San Diego, CA

450m FastE, Minneapolis, MN

http://www.systemsupportsolutions.com/casestudies.htm

Free Space Optical (FSO)

- **<u>FSO or Optical Wireless (OW):</u>**

- is a direct LOS optical communications.
- provides P2P connections (modulates visible or IR beams).
- offers high bandwidth and reliable communications over short distances.
- generates transmission carrier by deploying either a high-power light emitting diode (LED) or a laser diode while the receiver may deploy a simple photo detector.
- operates in full-duplex mode.
- transmits at rate ranging from 100 Mb/s to 2.5 Gb/s.
- depends largely on weather conditions.
- communicates over distances of several kilometers if there is a clear LOS between source and destination and enough transmitter power.
- uses optical fiber to build high-speed LANs, such as Gigabit Ethernet (GbE), at both source and destination.

Radio-over-Fiber (RoF)

- **RoF**

  - integrates optical fiber networks and wireless networks.
  - allows an optical link to transmit a modulated radio frequency (RF) signal.
  - is transparent against modulation.
  - supports various digital formats and wireless standards in a cost efficient manner.
  - avoids frequent handovers of fast moving users in cellular networks (train example).
  - operates in full-duplex mode.
  - transmits at rate 2.5 Gb/s over 40 km.
  - provides both P2P and point-to-multipoint connections.
  - supports various of cost-efficient design approaches.

FSO vs. RoF

Features	FSO	RoF
Connectivity	Point-to-point	Point-to-point and point-to-multipoint
Transmission mode	Full duplex	Full duplex
Scalability	High in terms of bandwidth Low in terms of user and service	Low in terms of bandwidth High in terms of user and service
Availability	Low in fog High in rain	High in fog Low in rain
Interference	Background sunlight	Electromagnetic signals
Spectrum licence	Not required	Required

FiWi Network Architectures

- Generic Archs.: Integrate the EPON and WiMAX networks:
  1. Independent.
  2. Hybrid.
  3. Unified Connection-oriented.
  4. Microwave-over-Fiber.

- Archs. based on WiFi technology (R&F):
  1. Optical unidirectional fiber ring.
  2. Optical interconnected bidirectional fiber ring.
  3. Optical Hybrid star-ring network.
  4. Optical unidirectional WDM ring.

Independent Arch.

- WiMAX and EPON networks operate independently.
- WiMAX BS serving mobile nodes.
- BS are attached to an EPON ONU.
- WiMAX and EPON networks are connected via a common standardized interface (e.g., Ethernet).

Hybrid Arch.

- ONU-BS integrates the EPON ONU and WiMAX BS in both hardware and software.
- The integrated ONU-BS controls the dynamic bandwidth allocation of both the ONU and BS.

Unified Connection-oriented Arch.

- Similar to the hybrid architecture, this approach deploys an integrated ONU-BS.
- Instead of carrying Ethernet frames, WiMAX MAC protocol data units (PDUs) containing multiple encapsulated Ethernet frames.
- By carrying WiMAX MAC PDUs, WiMAX's connection-oriented (with the ability to grant bandwidth finely) can be used rather than EPON's queue-oriented bandwidth allocation.

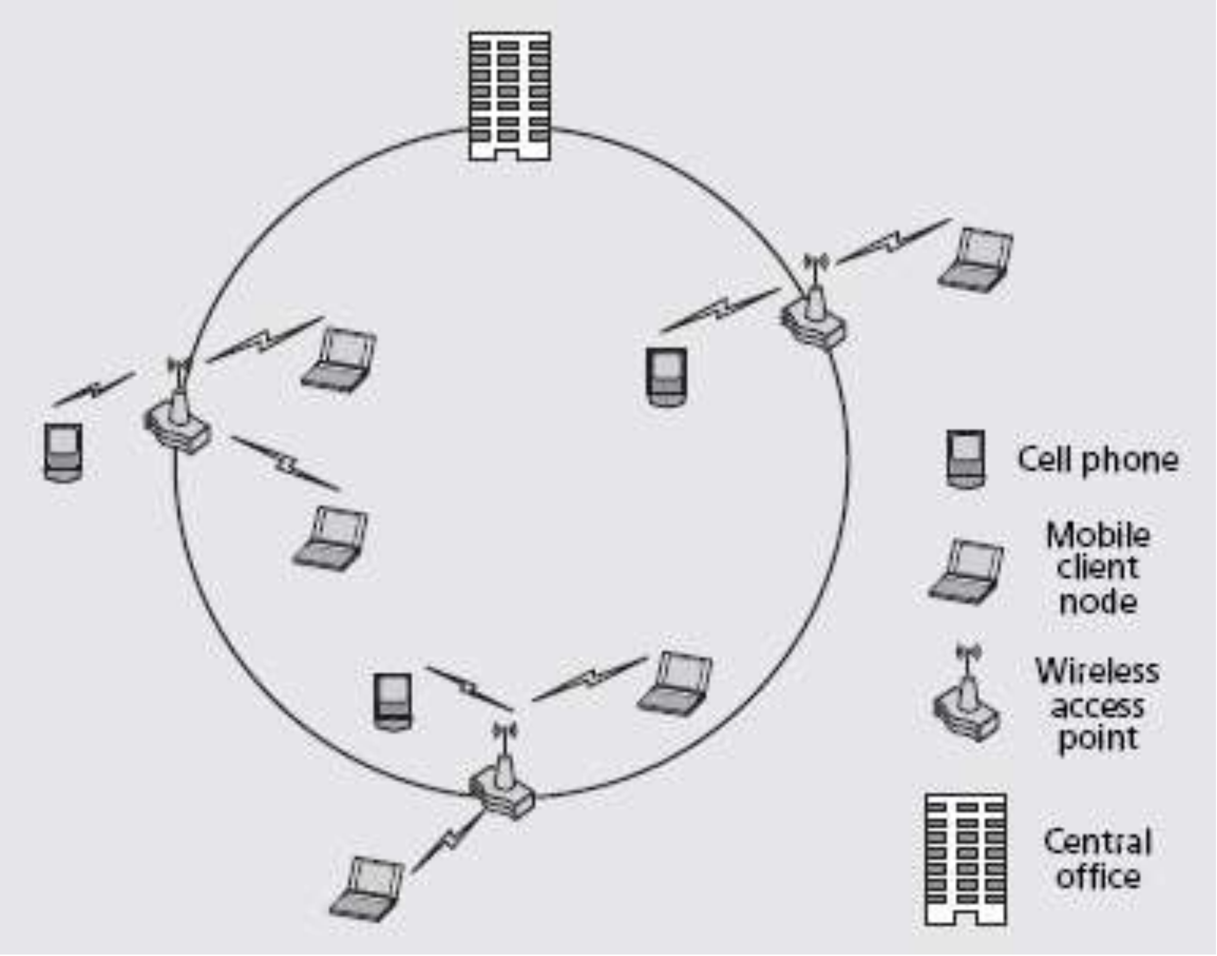
Microwave-over-Fiber Arch.

- The WiMAX signal is ***modulated*** on a ***wireless*** carrier frequency, and is then ***multiplexed and modulated*** together with the ***baseband EPON*** signal onto a common optical frequency (***wavelength***) at the ONU-BS.
- The CO consists of the ***EPON OLT*** and a central WiMAX BS (called: ***macro-BS***).
- The OLT processes the baseband EPON signal, while the macro-BS processes data packets originating from multiple WiMAX BS units.

Optical unidirectional fiber ring

- Interconnects the CO with multiple WiFi-based wireless access points (WAPs) by unidirectional fiber ring.
- The CO is responsible for
  1. managing the transmission between mobile nodes (MNs) and their WAPs.
  2. acting as a gateway to other networks.
- All MNs participate in the topology discovery process.
- Each MN periodically updates its WAP with neighbors info.
- WAPs are able to estimate the distances between MNs and compute routes.
- Multihop relaying is used to extend the range.
- The CO can assign more wavelength channels on the fiber ring to accommodate multiple services such as WLAN and cellular radio network.

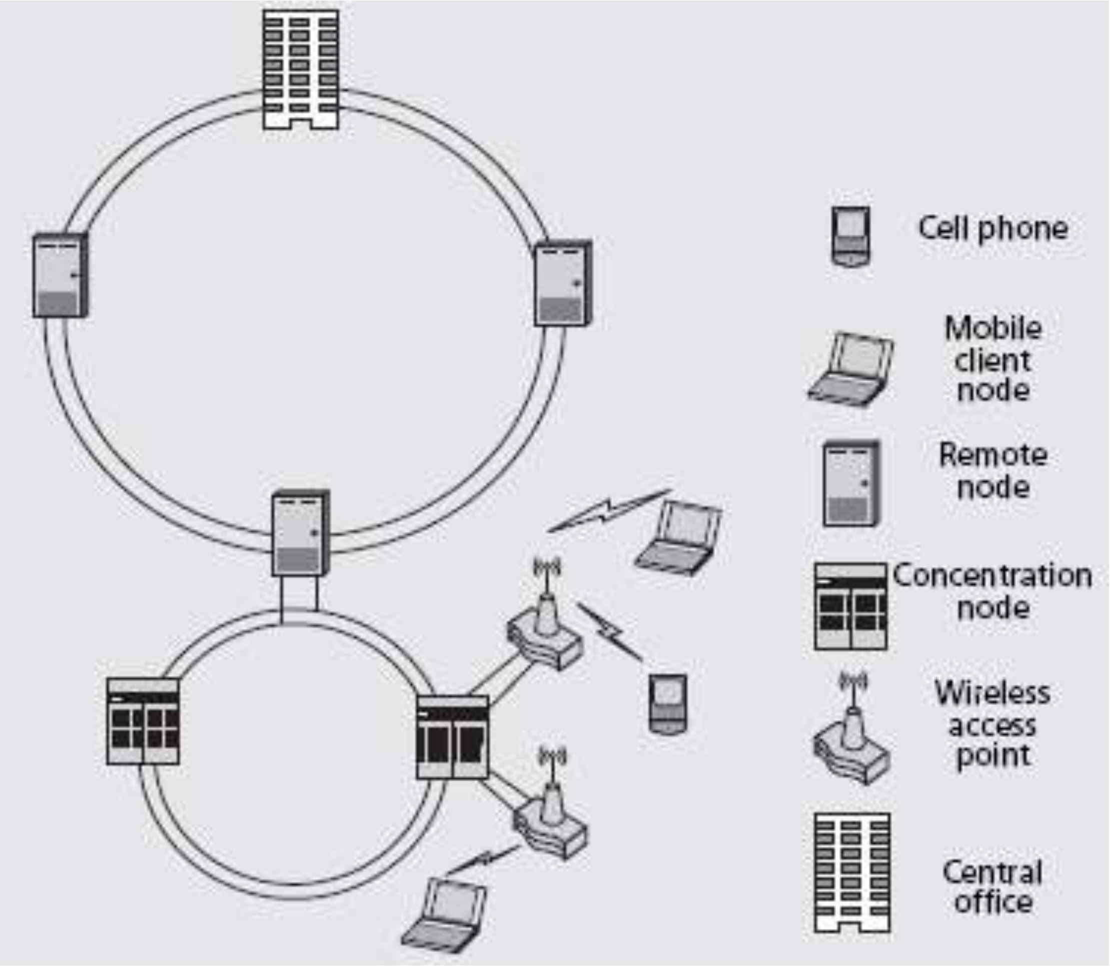
Optical unidirectional fiber ring



Optical interconnected bidirectional fiber ring

- Is a two-level bidirectional path protected ring (BPR) architecture.
- The CO interconnects remote nodes (RNs) via a dual-fiber ring.
- Each RN cascades WAPs through concentration nodes (CNs).
- For protection, the CO is equipped with two sets of devices (normal and standby).
- Each RN consists of a protection unit and a bidirectional wavelength add-drop multiplexer.
- The WAP comprises an optical transceiver, a protection unit, up/down RF converters, and an antenna.
- Each WAP covers up to 16 MNs.
- Under normal operating conditions, the CO transmits downstream signals in the counter-clockwise direction via RNs and CNs to the WAPs.
- If a fiber cut occurs between two RNs or between two CNs, their associated controllers detect the failure by monitoring the received optical signal and then switch to the clockwise protection ring.
- If a failure happens at a WAP, the retransmitted signals are protection switched through other optical paths by throwing an optical switch inside the affected WAP.
- This architecture provides high reliability, flexibility, capacity, and self-healing properties.

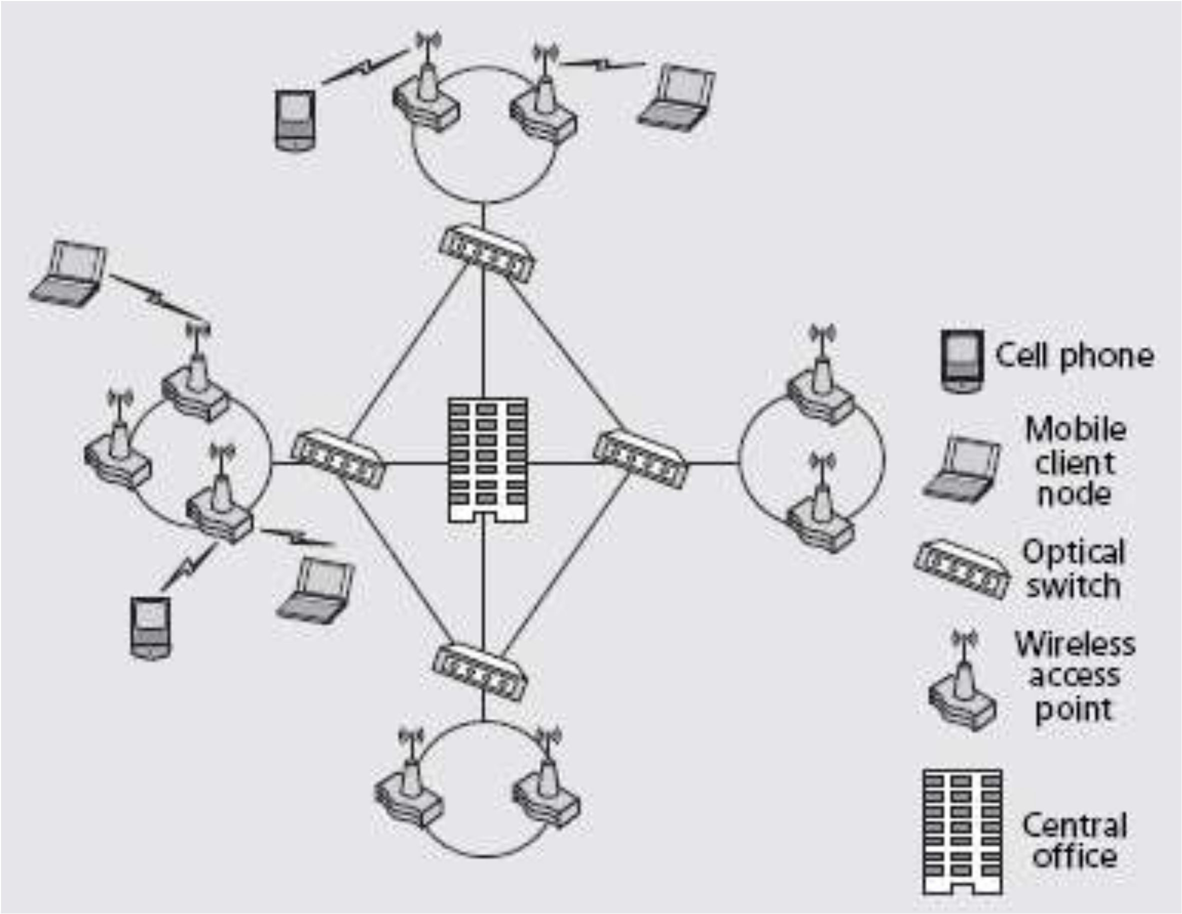
Optical interconnected bidirectional fiber ring



Optical Hybrid star-ring network

- Combines optical star and ring networks.
- Each fiber ring accommodates several WiFi-based WAPs, and is connected to the CO and two neighboring fiber rings via optical switches.
- The optical switches have full wavelength conversion capability, and interconnect the WAPs and CO by shared P2P lightpaths.
- Maintains load balancing.
- In the event of one or more link failures, the affected lightpaths are dynamically reconfigured using the redundant fiber paths of the architecture.

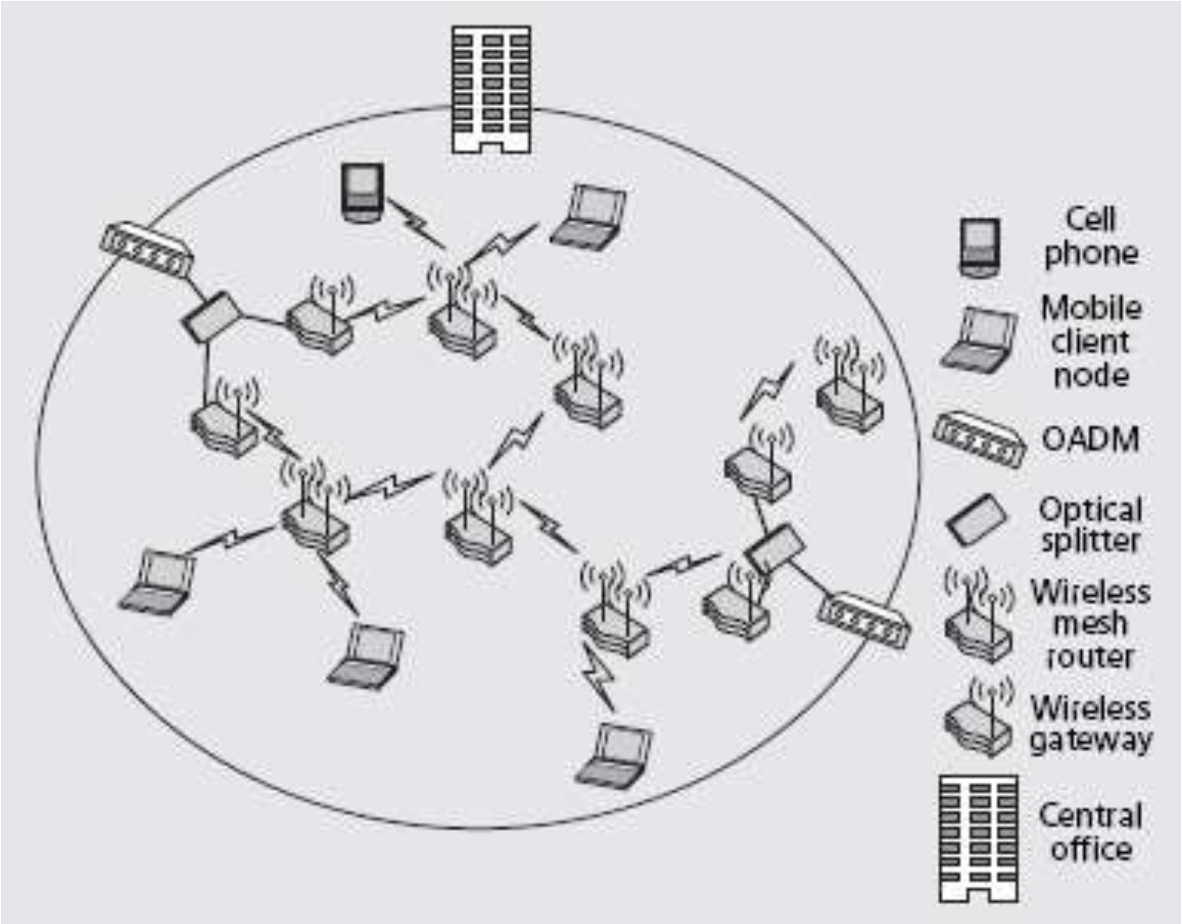
Optical Hybrid star-ring network



Optical unidirectional WDM ring

- An optical WDM backhaul ring with multiple single-channel or multichannel PONs attached to it.
- Wireless gateways are used to bridge PONs and WMNs.
- Since the optical backhaul and WMN use different technologies, an interface is defined between each ONU and the corresponding wireless gateway.
- Considers load balancing issues.
- Provides cost effectiveness, bandwidth efficiency, wide coverage, high flexibility, and scalability.
- The dynamic allocation of radio resources enables cost-effective and simple handovers.

Optical unidirectional WDM ring



Future Technological Challenges

- determine a feasible, scalable, and resilient ***architecture*** along with the corresponding enabling technologies.

  - seamlessly integrate the first/last mile optical fiber access solutions (i.e., FTTX) with the heterogeneous broadband wireless networks .

- Study new ***approaches*** to exploit the huge ***bandwidth*** available in optical access networks for offloading bandwidth-limited wireless networks.

- The design and evaluation of powerful load ***balancing and reconfiguration*** techniques to improve the bandwidth efficiency of future FiWi networks:

  - including reconfiguration techniques for unpredictable traffic.

- ***Routing in WMNs*** remains a critical issue, and designing efficient routing protocols that are aware of the bandwidth allocation on PON is more challenging:

  - fairness.
  - load balancing.

Future Technological Challenges

- Design ***QoS-aware routing*** protocols in WMNs is still an open issue.

- Study powerful end-to-end ***resource allocation*** techniques in FiWi networks.

- Resiliency against ***failures*** is another challenge of future FiWi networks.
  - FiWi networks should allow WMN gateways to interconnect with the optical backhaul through multiple points in order to enable multipath routing and improve their survivability.
  - the optical backhaul should implement appropriate protection switching functions to deal with network element failures rapidly.

- ***Implementation simplicity*** will be key to the commercial success of FiWi networks.
  - reducing the installation and protection costs by transferring expensive devices and complex functions to the central office is a costeffective approach for FiWi networks.
  - feasible modulation formats for optical/RF signal conversion are needed.

Q & A

Thank you.