Integrated Optical-Wireless Networks and the Applications That Will Use Them

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We can’t predict the future, but we can have a perspective on it.

我们不能预测将来，但可对未来有我们的看法
The Age of Wireless

A.G. Bell’s Photophone
1880
(The first optical-wireless integration?)
People love wireless and want more.

4G (probably LTE-Advanced) is coming.

The mobile Internet will carry hugely increased traffic, most of it visual, in the near future.
Evolution of 3G Cellular Standards

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<th>2G</th>
<th>2.5G</th>
<th>3G</th>
<th>4G</th>
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<td><strong>World</strong></td>
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<td>GSM (TDMA)</td>
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<td>WCDMA (UMTS)</td>
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<td>IS-95A (CDMA)</td>
<td>IS-95B (CDMA)</td>
<td>1x (CDMA2000)</td>
<td>EV-DO (CDMA2000)</td>
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</tbody>
</table>

Source: Computer Desktop Encyclopedia, 2009
Cisco Mobile Data Traffic Forecast


For more details, see Appendix B: Forecast and Methodology.
Source: Cisco VNI Mobile, 2010
... with video dominating the mix
The success of broadband wireless requires close integration with optical networks

A. Radio and fiber (R&F), e.g., for backhaul of data traffic from a wireless domain to a network gateway
B. Radio over fiber (RoF)

For cheap base stations, concentrating radio signal processing for multiple base stations in one node. Offers economies of scale in processing and potential energy savings.

A research challenge:
Replace analog RoF with digital RoF to improve signal quality (Will it be possible with super high capacity optical networks? Or some kind of digital compression?)
C. Sharing of technologies between radio and optical domains
Example: OFDM PON

- Cost-effective spectral efficiency and chromatic dispersion resilience
- Fine-grained, dynamic bandwidth allocation and single-platform support for heterogeneous services, including radio backhaul

MAC-level issues in extending wireless with optical transmission

1. Wireless protocol all the way (may have timeout problems due to processing and propagation delays)

2. Protocol conversion between wireless and optical segments (added complexity)
3. Possible solution: New integrated optical-wireless MAC protocol among base stations, RNCs and network gateways to support reliable media flows for multimedia applications.


Maier & Ghazisaidi suggest hierarchical scheduling and hybrid access control, and avoiding any distributed access contention protocol in wireless domains.
Whichever MAC-level solution is chosen, the use of different physical network segments suggests attention to QoS translations and cross-layer design.

Air interface:
Priority scheduling and backoff

Wireless domain:
control & resource allocation

Internet domain resource allocation

Optical domain resource allocation

RNC

Network gateway

DiffServ mappings

Optical network

Frame/subchannel allocations

WiFi

WLAN resource allocation, centralized or distributed
4G mobile communications requires a strong broadband optical-wireless infrastructure

Important research project: The European FUTON Optical network support of broadband wireless access

A remarkable new component: Coordinated Multipoint (CoMP)
- An LTE-A feature to reduce or eliminate mutual interference and thus greatly increase capacity.
- Multiple base stations form a large distributed antenna for multiple mobile devices in a virtual MIMO system.

DBWS: Distributed Broadband Wireless System (Coordinated Multipoint)
CoMP implementation is an open research issue.

One approach: singular value decomposition of the matrix channel (multiple base stations to multiple users), either single or dual layer, with appropriate assignments of spatially orthogonal subspaces to different user channels.


[We’re working now on an article for IEEE Communications Magazine.]
Femtocells: Do we need them?

The argument against:
We have broadband WiFi in homes and offices, so who needs it?

The arguments for:
-A femtocell may serve a user population beyond the residents of a particular home or office in which it is located. [Franchise business strategy.]

-Enhanced capacity and quality of service for delivery of broadband applications when users are closer to a base station.

-Offload traffic from the cellular operator’s backbone network.

-Possibilities for low-level caching for content delivery networks (CDNs)

Challenge: Seamless mobility across femtocell-macrocell boundary
So what are the multimedia applications that need all this?

Needs and desires, social and economic forces, technologies, and infrastructure drive and inspire the applications.
Social and economic

Energy conservation, environmental responsibility, and helping society have become as important as performance specifications for the success of new technologies, services and products.

Telecom Italia tests solar powered base station
Needs and desires include:

Rich content
Social networking
Environment-to-environment interaction
Emergency/priority communications
Environmental monitoring and control
Tracking children, pets, yourself
Health care
Education
Personal financial transactions

...... and many more
Rich content with handoff-capable “three screens” access from anywhere, video format translations where needed, and better and more customized video content.
Social Networking – if you have a lot of time to spare
Our professional societies are also trying it
Environment to environment (E2E) interaction

A new paradigm for electronic communication, extending multimedia teleconferencing, in which users experience the essence of each other’s environment as they would in a face to face situation.

Each environment is equipped with different types of sensors, as required to detect presence and activity of objects, and appropriate displays deliver information from the sensors to the communicating parties.

Refs:
2. www.calit2.uci.edu/calit2-newsroom/itemdetail.aspx?cguid=56c28e1e-4fb5-46e4-83bd-95e5b1662f09
Emergency communications

Provider Network A Infrastructure (Police)

Access Network A

First responder Mobile Ad-hoc Network A

Wireless Link

First responder Mobile Ad-hoc Network B

Fire Dept.

Wireless Link

Access Network B

Provider Network B Infrastructure (Fire Department)

www.nist.gov/itl/antd/emntg/images/firesystem.gif
Better to make a virtual network within the public communications infrastructure than separate, difficult-to-interconnect police, fire, medical networks.

[As recently suggested by Adam Drobot, VP-Research, Telcordia Technologies]
Environmental monitoring and control

Earthquake/tsunami

weather conditions

water quality

smart grid

nuclear power plants
Smart Grid – A new architecture for the electrical power distribution network

-Automated metering
   Two-way communication with end-user meters and appliances
   End user choice of service parameters and costs
   Automated load control including price differentials and time-
   and demand-sensitive appliance control.

-Control of devices within the transmission grid
   Operate devices with greater efficiency with respect to outages,
   recovery, connects/disconnects

Ref: Video from IEEE Energy 2030 Conference
www.ieee.org/portal/site/ieeetv/menuitem.6ce799f946c20d660374ca695bac26c8/
index.jsp?pName=ieee.tv.viewer&path=membport/ieee_tv&file=SPC_SmartGrid.xml&vid=107465&play=true
Smart grid involves optical communication (and, for some sensors, wireless as well) because powerline communications uses the powerline only up to the distribution transformer.

**IEEE P1901**

- Electric Utility
- Local distribution transformers
- Router
- Fiber to the transformer
- Low voltage
- Medium voltage
- Residential gateway
- Optical Internet
- ISP
- Element Management Layer
- BoPL Operations Support System
- In-home network

In-home network

- In-home network
Smart Grid (IEEE P2030)

**Systems Approach**
- Interconnection & Interfaces
- Technical Standards
- Advanced Technologies
- Systems Integration

Source: grouper.ieee.org/groups/scc21/dr_shared/2030/
Tracking premises, children, pets, yourself, ...
GPS cat tracker (CatTraQ)
weirdnewsfiles.com/tag/cattraq/, www.mr-lee-catcam.de/cattraq/

This 2008 implementation was just a GPS recording device later read out and displayed on a Google map. Similar devices are available for hikers and runners. Weighs 22g. Not yet communicating.

Cat can also carry a small video camera!
Health care: Remote medical diagnosis and treatment, patient monitoring.
Telstra CTO Hugh Bradlow noted in April, 2010 that full high definition contact with caregivers is a significant innovation challenge.
Remote surgery (maybe not tomorrow)
Interactive education, both real time and archived. Online university and high school course materials are just the beginning of a major educational initiative to serve people of all ages in both rural and urban areas.
Personal financial transactions
e.g. purchases of goods and services from wireless handheld devices
(May include multimedia information delivery to the customer)
images.pingmag.jp/images/article/vencmode.jpg
Can mobile networks become new financial institutions, effectively bypassing the banks for funds transfers and commercial transactions, especially in the developing world where few have bank accounts but almost everyone has a cell phone?
Ref: SBA Technologies, www.sba-tech.com
CONCLUSIONS

- Optical and wireless networking are close partners in a broadband infrastructure supporting a huge volume of multimedia traffic.

- There are research challenges in coordinated multipoint for dense populations of broadband wireless customers, in MAC functionality across optical and wireless domains, in delivering content effectively to “three screens”, in realizing “green” communications and computing, and in many other areas not addressed here.

- Broadband applications are not limited to the usual video on demand.

- Engineers should, more than ever, be aware of social, cultural, and economic needs of human beings.
谢谢