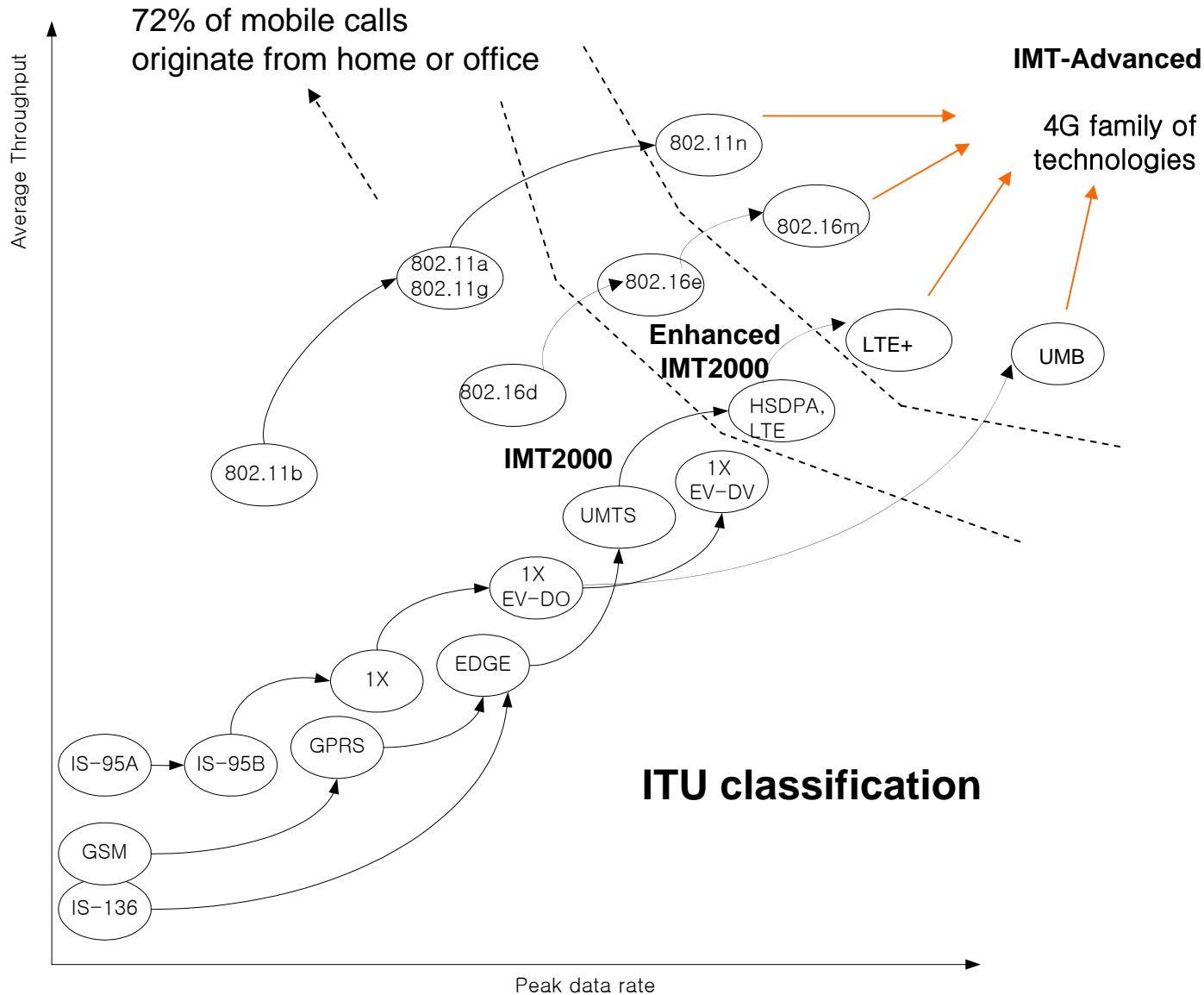


4G – Drivers and Challenges

Sampath Rangarajan
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Evolution of Wireless Technology



Challenges (High-level View)

- Radio (Air) Interface challenges
 - Increasing spectrum efficiency – bits/sec/hz
 - Capacity (cell throughput – peak and average)
 - Coverage (throughput to cell edge users)
 - Improved spectrum allocation
 - Choosing appropriate spectrum for 4G (based on spectrum requirements and availability)
 - Harvesting unused spectrum (cognitive radio networks) – 5 to 40 Mhz bands will be used
 - Power consumption, base-band processing cost etc.
- Network-level challenges
 - Support for mobility between multiple access technologies
 - Automatic network tracking and selection
 - Security and Privacy
 - QoS support
 - Backhaul design
 - All-IP access
 - Radio-on-fiber

Challenges (High-level View)

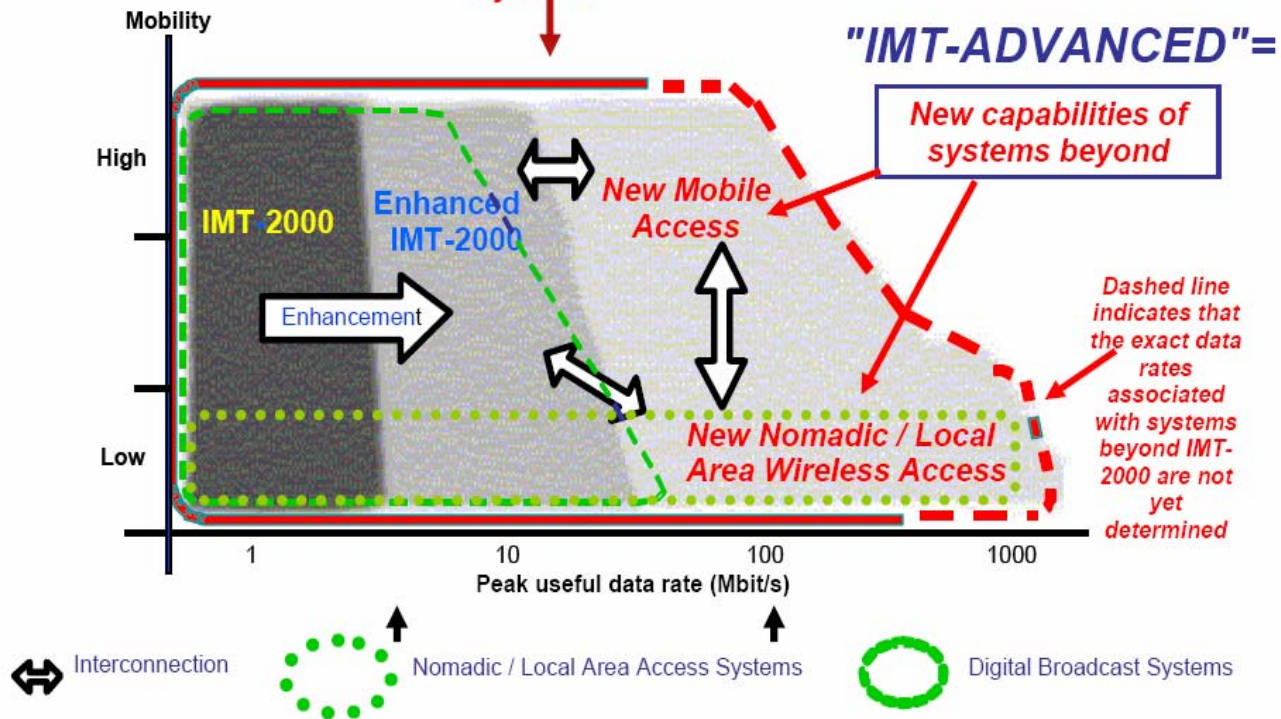
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ITU-R Expectations for IMT-Advanced



The "VAN diagram"...

Recommendation ITU-R M.1645



Document equivalent to ITU-R M.1457 (IMT-2000) to be developed this year

What do these expectations mean?

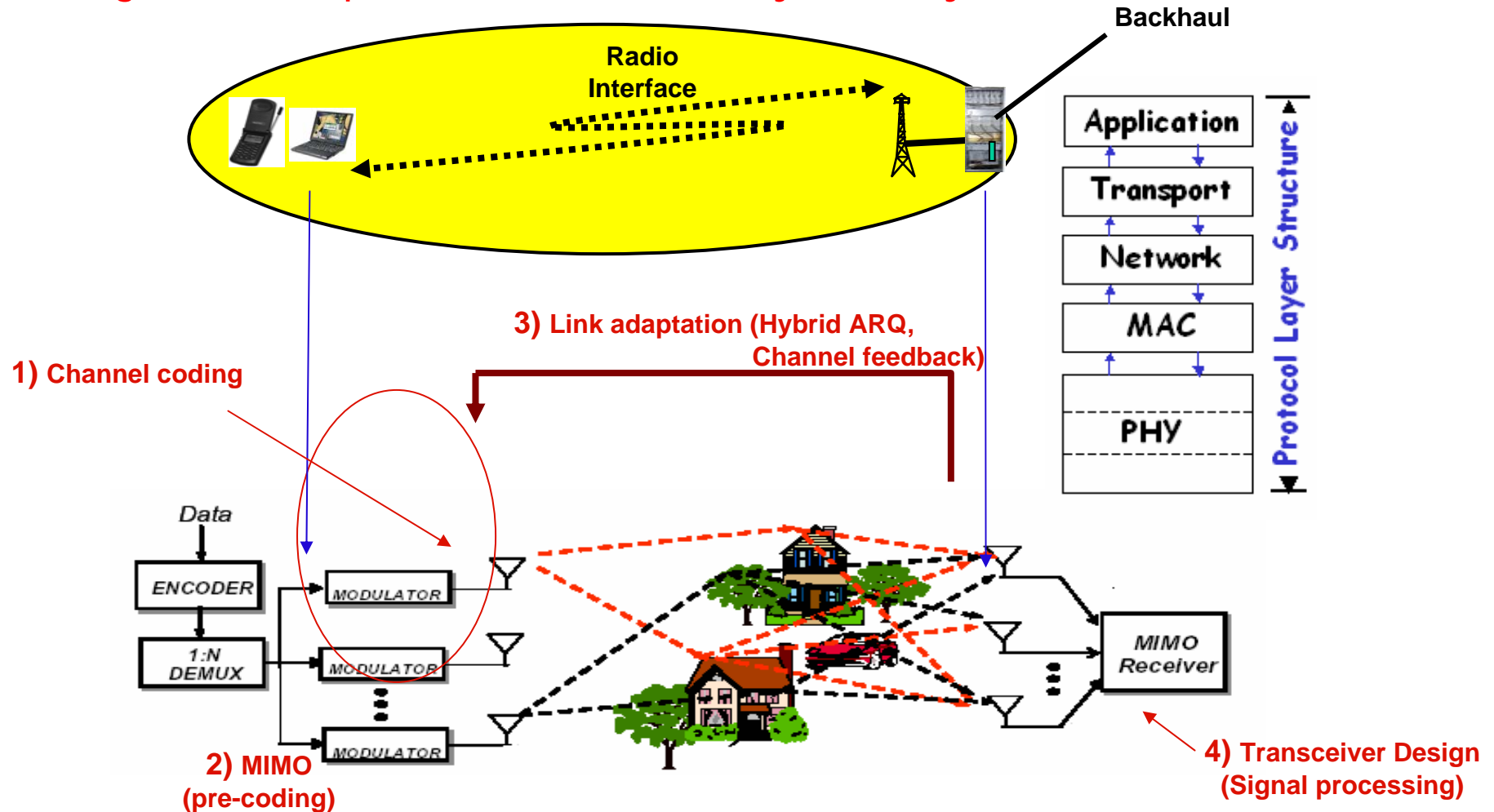
- Much increased spectrum efficiency compared to 3G
 - 3G Networks expected to support ~ 2 to 3 bits/sec/hz
 - Example - With 1.25 Mhz spectrum, EVDO Rev. A provides 3.1 Mbps peak data rate per sector
 - 4G Networks expected to support ~ 8 to 10 bits/sec/hz
 - 802.16m SRD specifies a requirement of at least 8 bits/sec/hz
 - Performance metrics that really matter are
 - Capacity in terms of per user average throughput
 - Coverage in terms of reasonable throughput to users at the cell edge
- Limited availability of usable spectrum
 - Only 136 Mhz of additional spectrum has been identified for IMT-Advanced (ITU-R - WP8F)
 - It is expected that 1280 to 1720 Mhz will be required by 2020

What are the solutions?

- Capacity improvement
 - Per user throughput is important
 - Micro, Pico cells – keep user density per cell constant
 - Adaptive antenna technologies – eg. Network MIMO
 - Differentiated bandwidth per user/application
 - QoS management at Phy/MAC
 - Cross-layer (Application-aware MAC scheduling)
- Coverage improvement
 - Relay networks (two-hop relays defined in 802.16j standard)
 - Femtocells to improve indoor coverage
- Spectrum availability improvement
 - Use of cognitive radio technology – spectrum harvesting in frequency, time, space

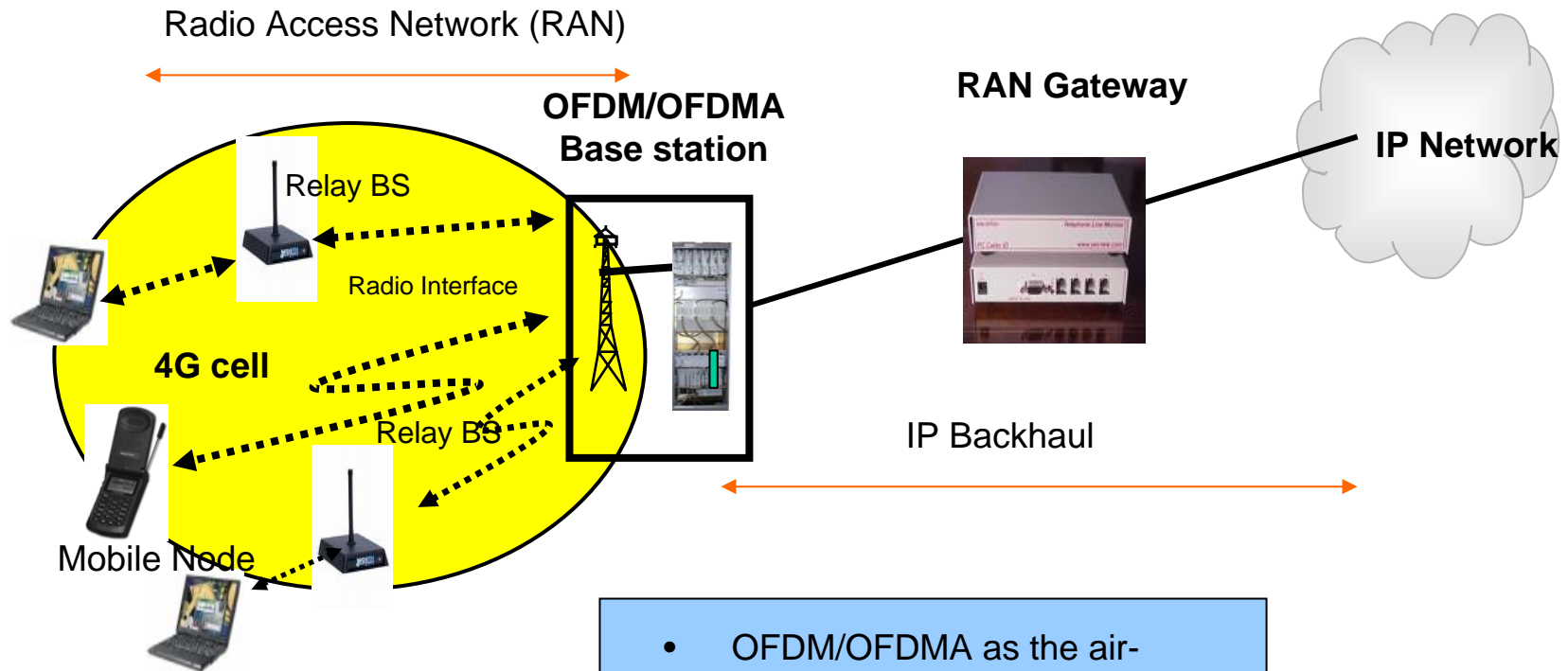
Traditionally (air-interface) focus has been on...

- Single link/cell performance at the Phy/MAC layer



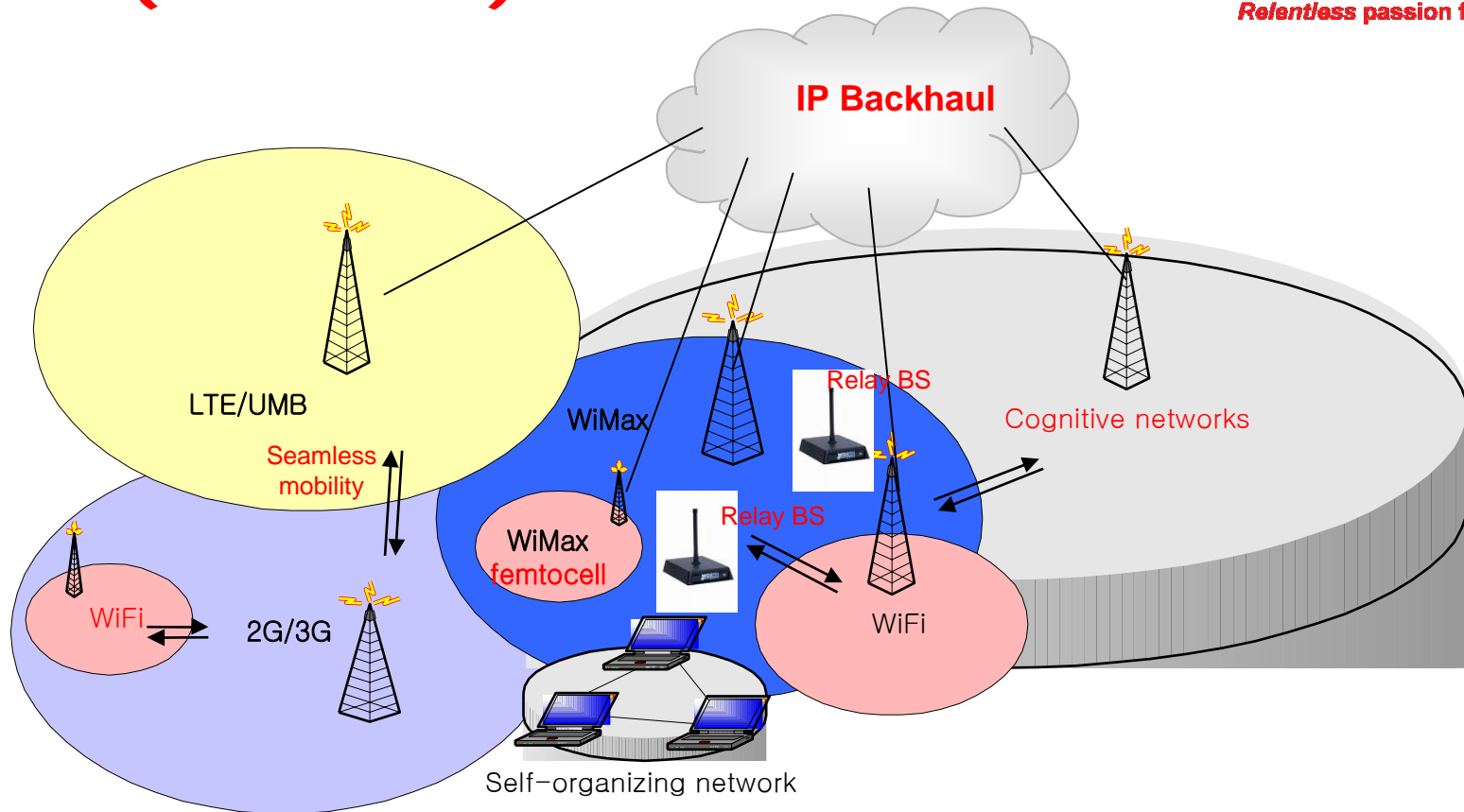
With 3.5G/4G, there will be a major architectural evolution

Single-Cell Evolution



- OFDM/OFDMA as the air-interface technology
- Macro/Micro/Pico/Femto cells
- Relay/Mesh networks
- All-IP Backhaul

System (Multi-cell) Evolution

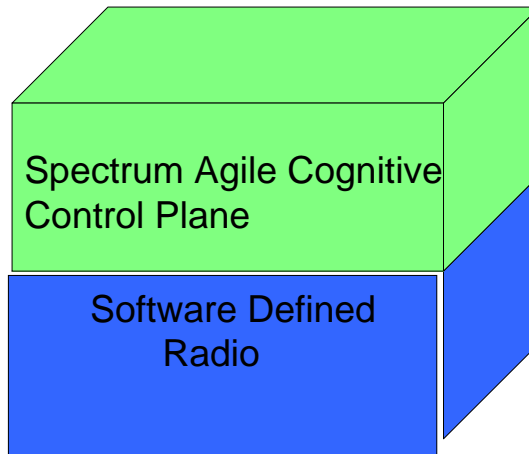


Network Interoperation and Cognition

- Heterogeneous network connectivity
- Mobility management (60 to 250 km/h)
- Cognitive/self-organizing networks
- **Open networks**

Cognitive Radio Networks

Now



A spectrum agile cognitive radio senses spectrum use by neighboring devices, changes frequency but gives priority to primary users within each frequency range

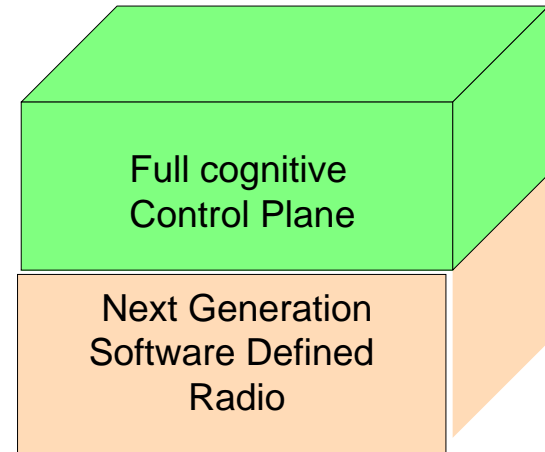
- *Spectrum sensing, sharing and management*
- *Spectrum mobility*

(IEEE 802.22)



Spectrum sensing
mobile

Future



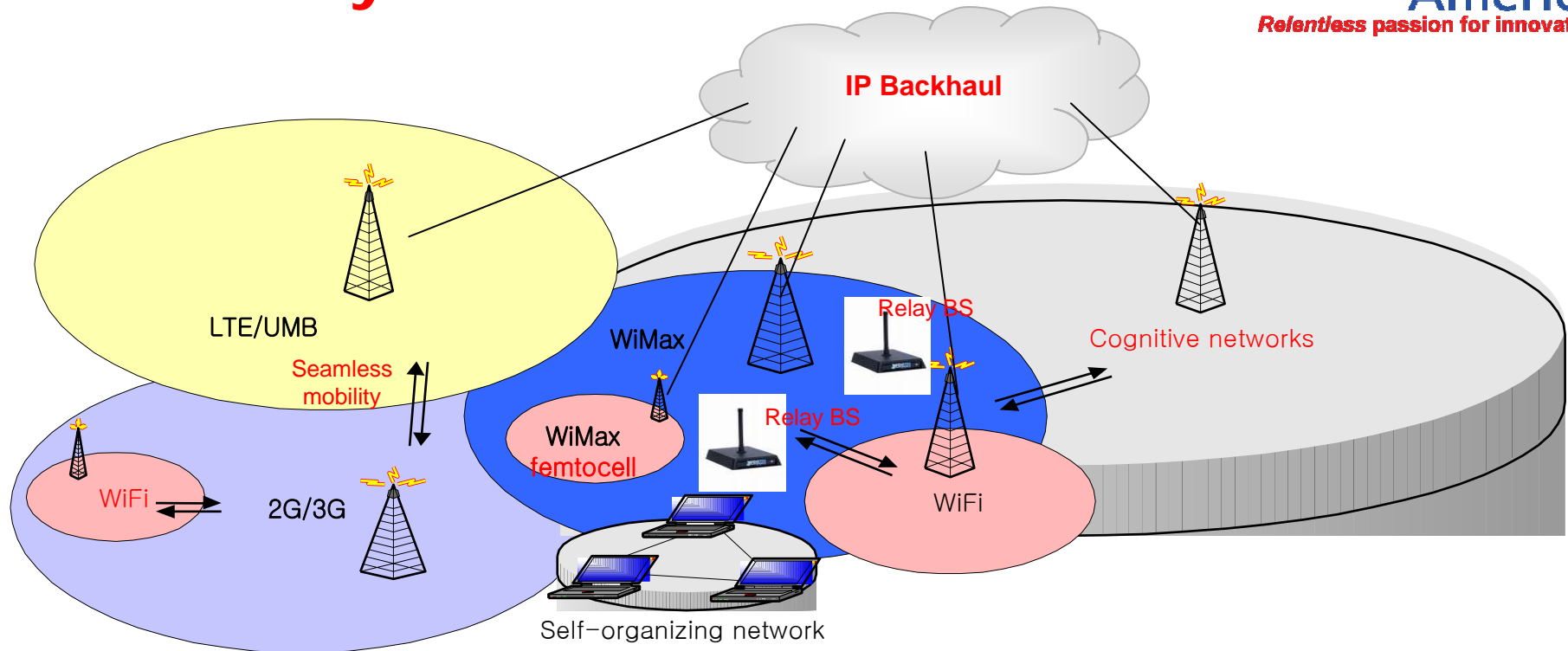
A full cognitive radio's capabilities include determining its location, sensing spectrum use by neighboring devices, changing frequency, adjusting output power or even altering transmission parameters and characteristics

- *Adaptive MAC*
- *Cognitive MAC to facilitate graceful handoff*
- *Cognitive OFDMA*
- *Self organization*



Fully cognitive mobile

Summary



Technology Requirements:

- ❑ Need for high per user bandwidth and higher spectral efficiency
- ❑ Support for heterogeneous Technologies and seamless mobility – LTE, WiMAX, UMB, WiFi – OFDM/OFDMA based
- ❑ System Evolution both within a cell and across multiple cells – smaller cells, relays for coverage enhancement
- ❑ IP backhaul support
- ❑ Dynamic deployment capabilities- eg. emergency response

Technical Challenges:

- ❑ Expected to support **8 to 10 bps/hz** at vehicular mobility
- ❑ Requires new techniques for improving capacity in terms of **per user application throughput**
- ❑ Requires new techniques for improving coverage - **reasonable bandwidth to cell edge users**
- ❑ **Flat architectures** enabled through evolution to IP backhaul