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4G – Drivers and Challenges

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Evolution of Wireless Technology

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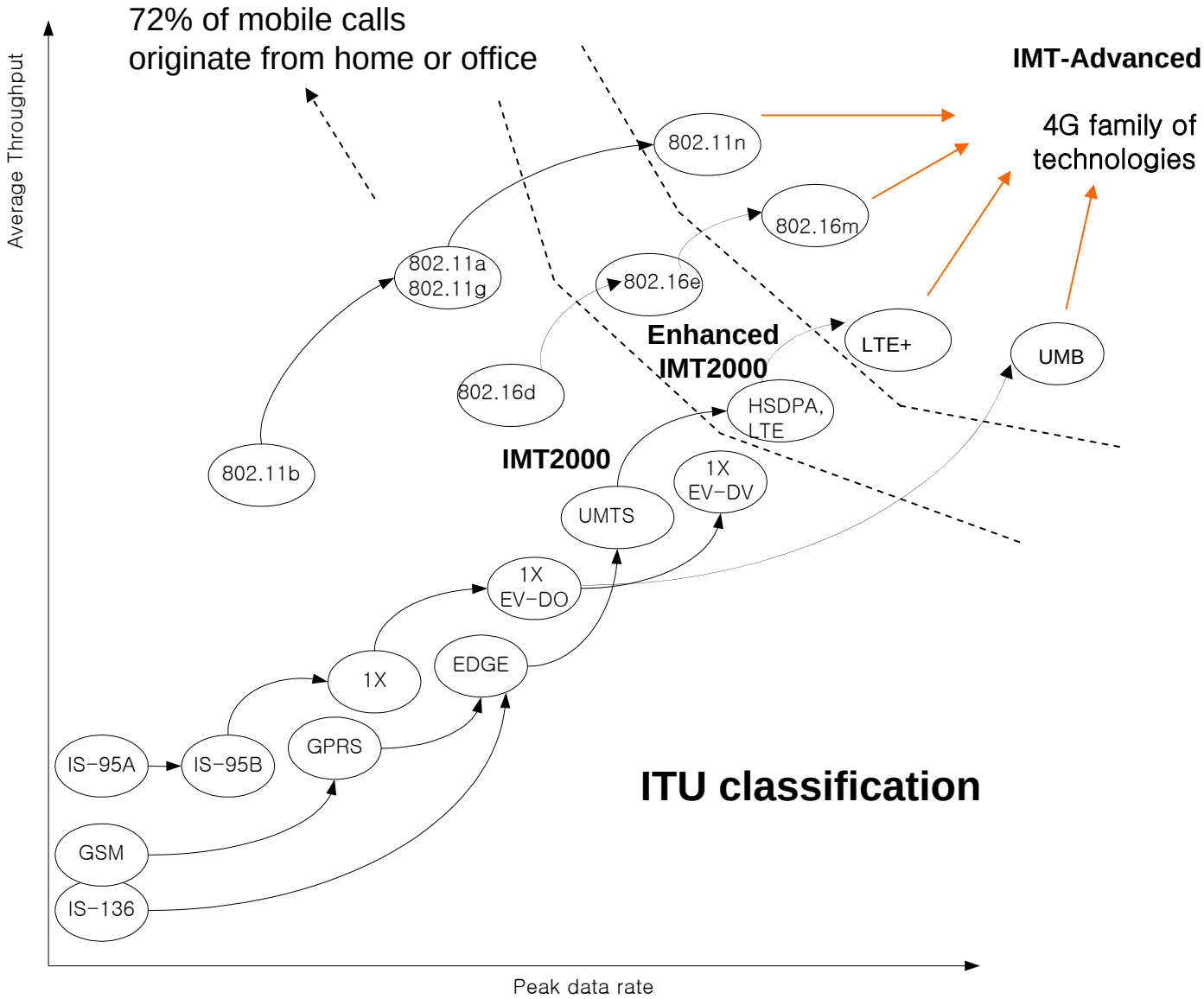

Challenges (High-level View)

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- 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

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ITU-R Expectations for IMT-Advanced

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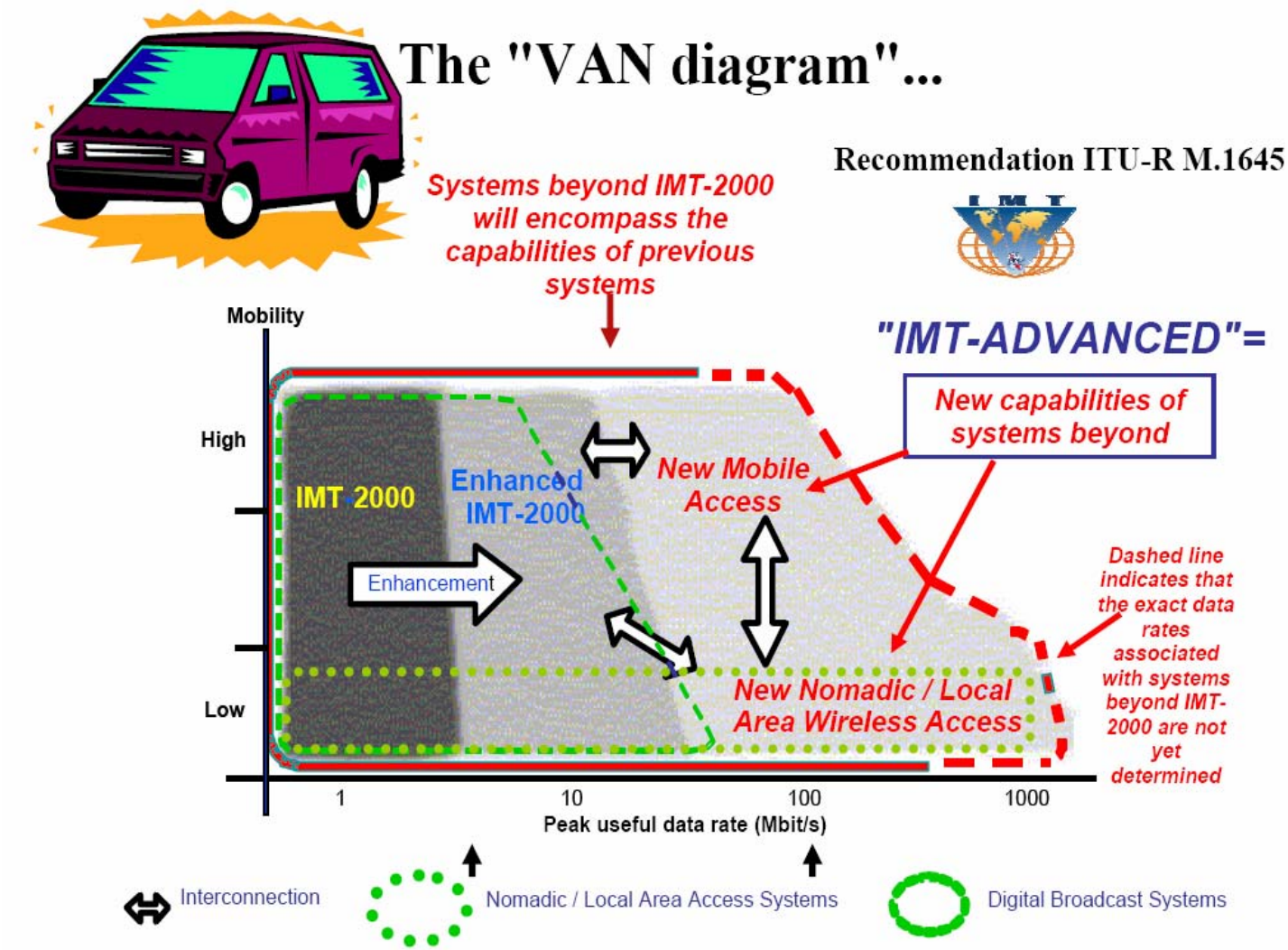

Document equivalent to ITU-R M.1457 (IMT-2000) to be developed this year

What do these expectations mean?

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- 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?

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- 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…

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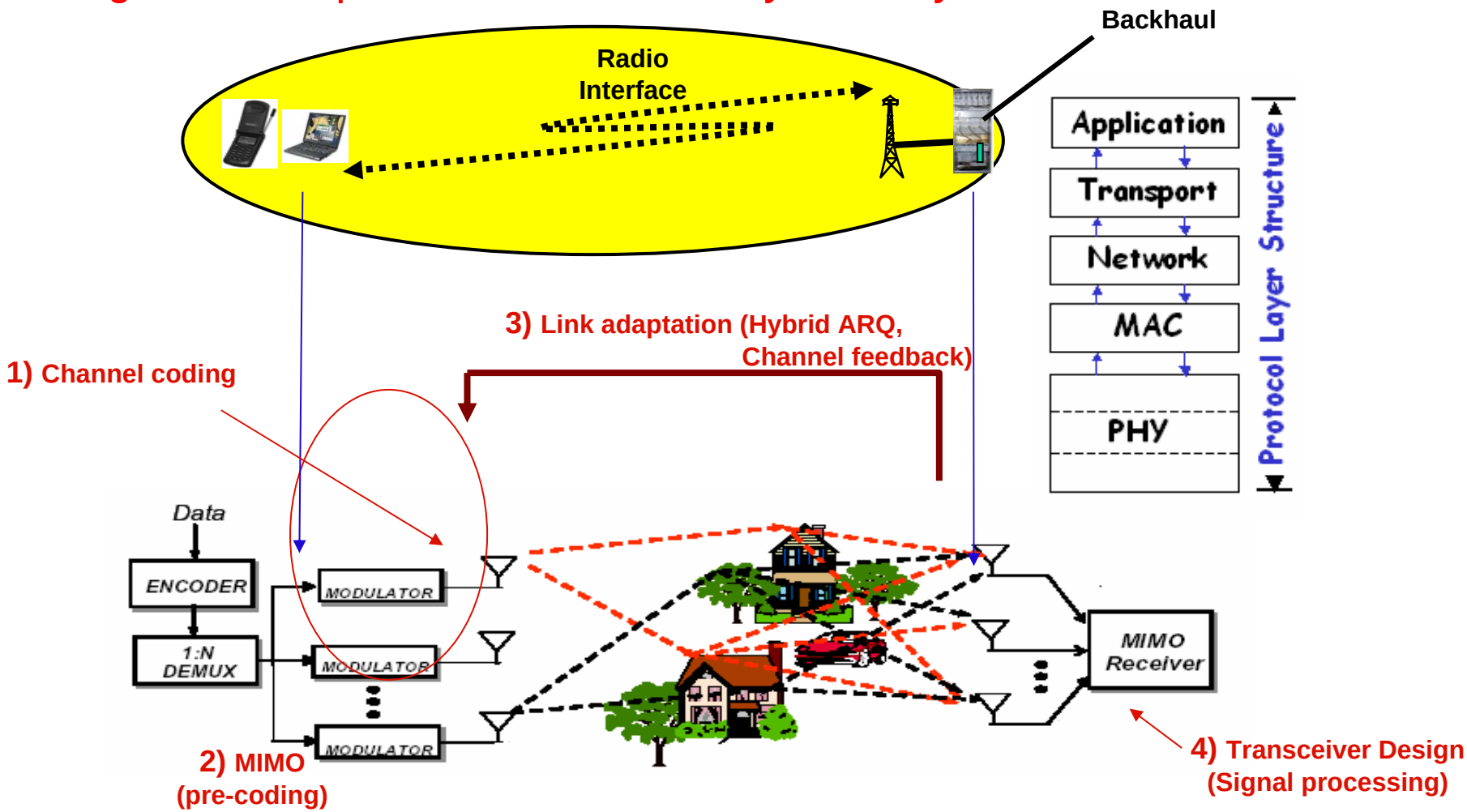
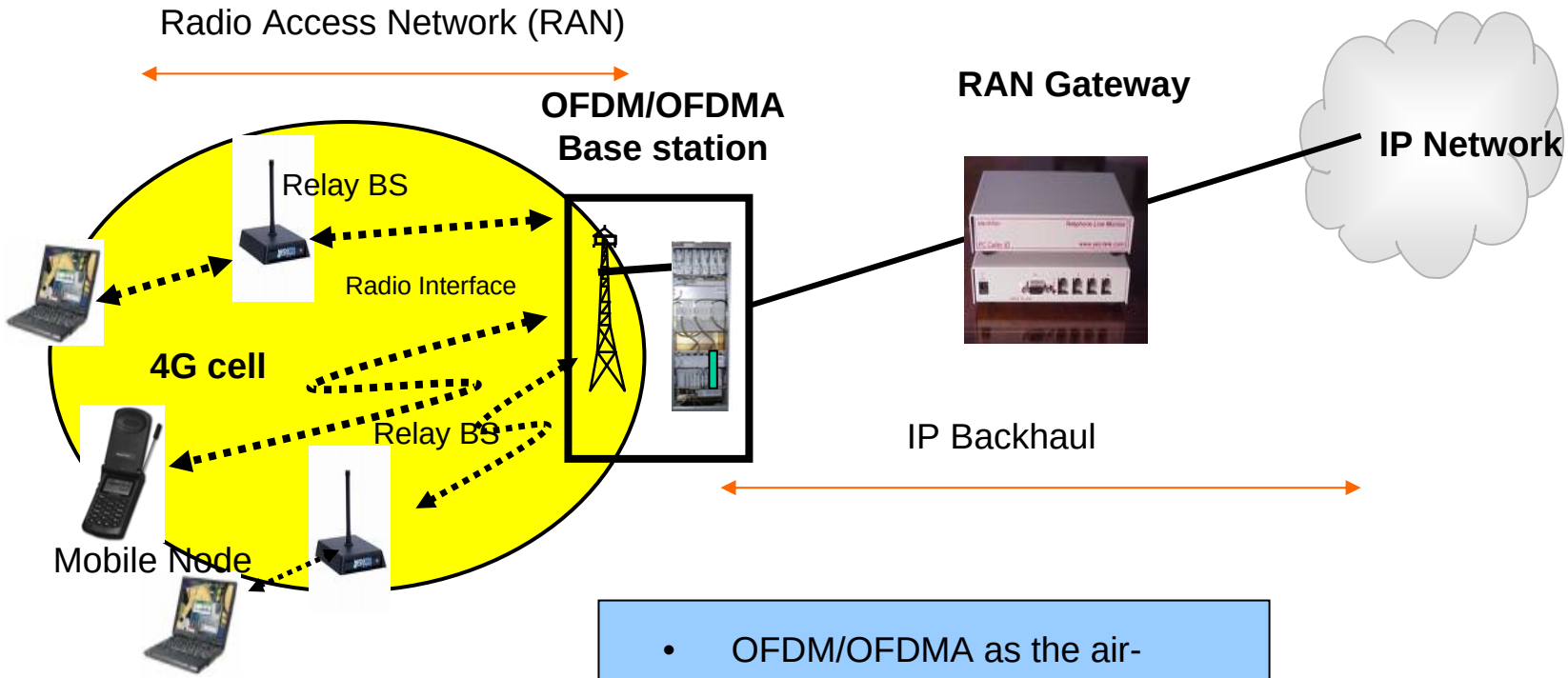
- Single link/cell performance at the Phy/MAC layer



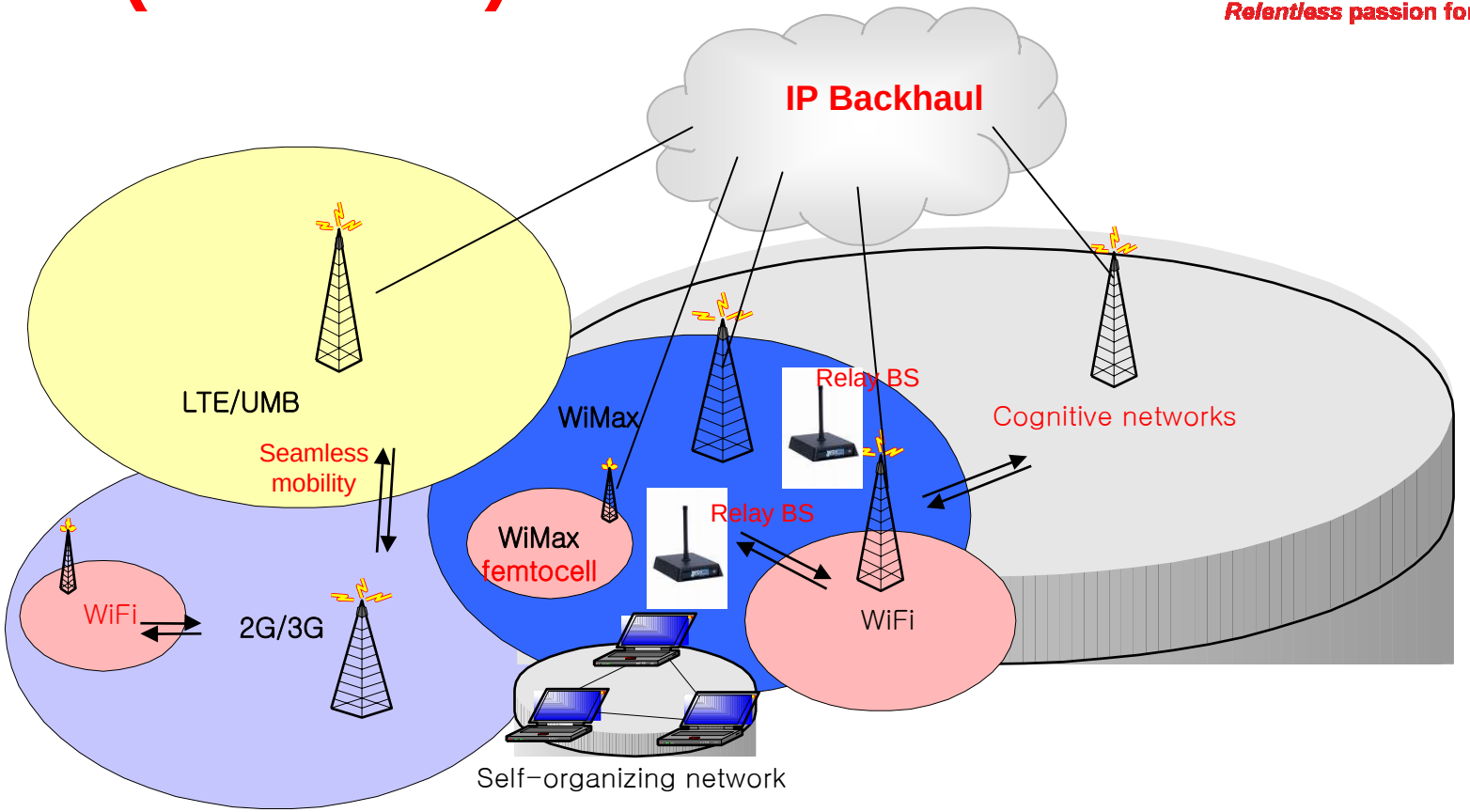
With 3.5G/4G, there will be a major architectural evolution

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

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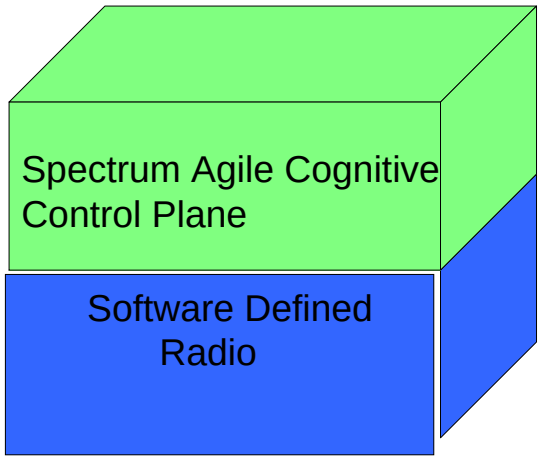
Now



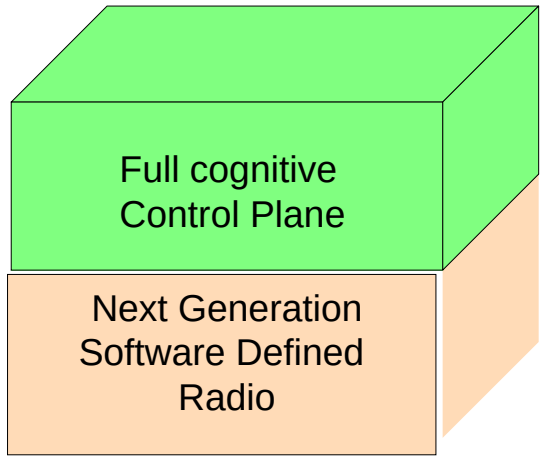
A spectrum agile cognitive radio senses spectrum use by neighboring devices, changes frequency but gives priority to primary users within each frequency range

- *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

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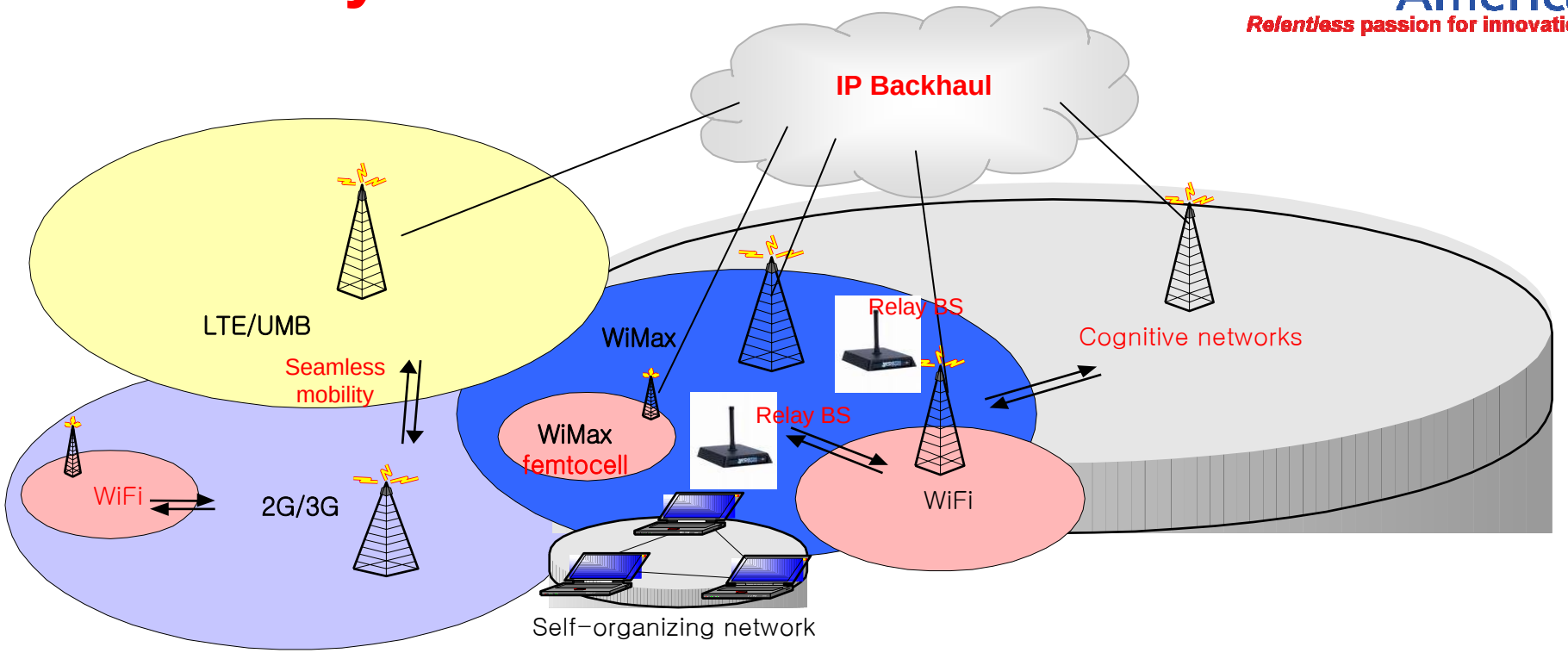

Technology Requirements:

- ❑ 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 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