Mobile Broadband Internet Access
What Comes Next?

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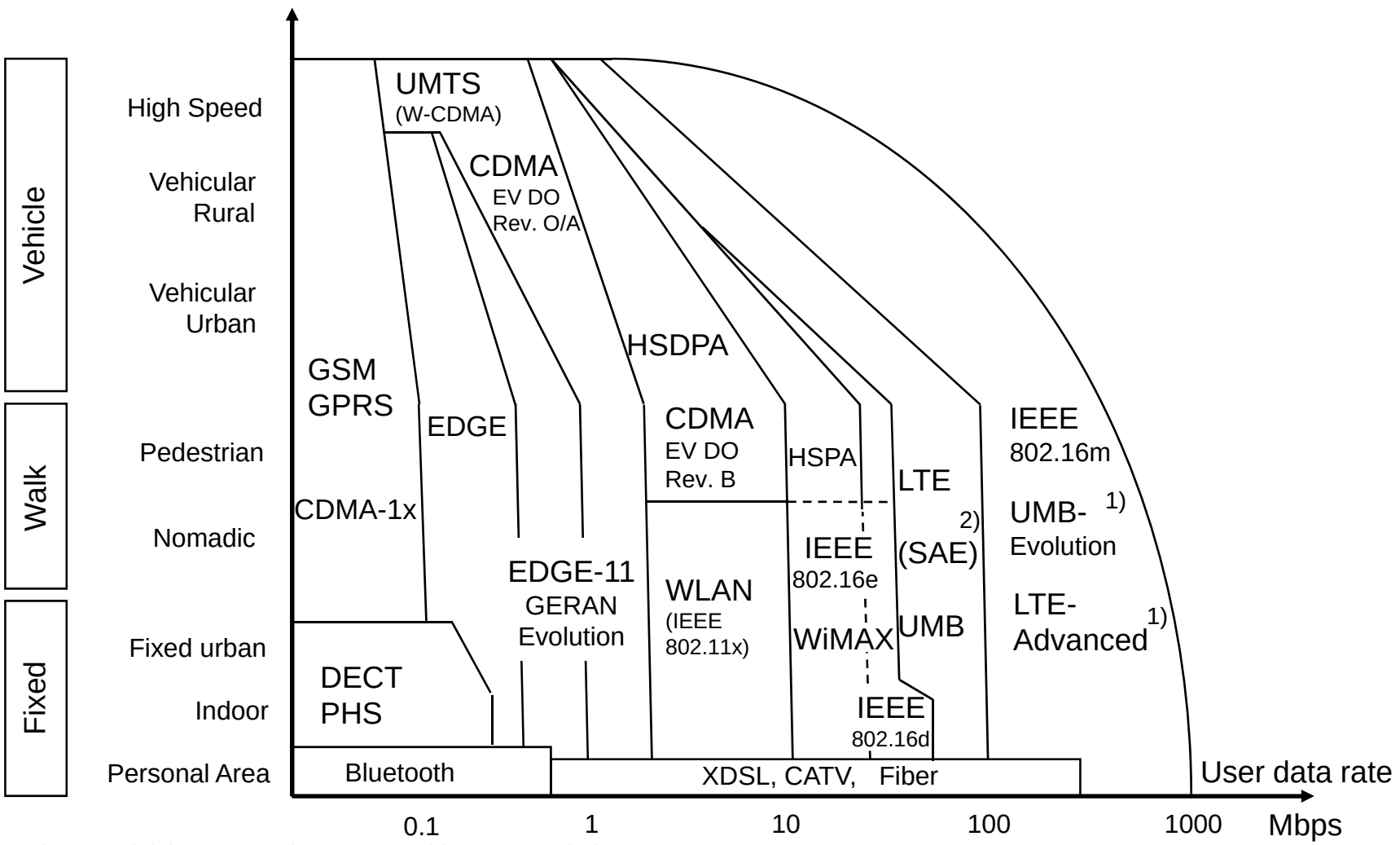

1) non-official name; 2) System Architecture Evolution

Source: Takagi/Walke: Spectrum Requirements Planning in Wireless Communications, J. Wiley 2008

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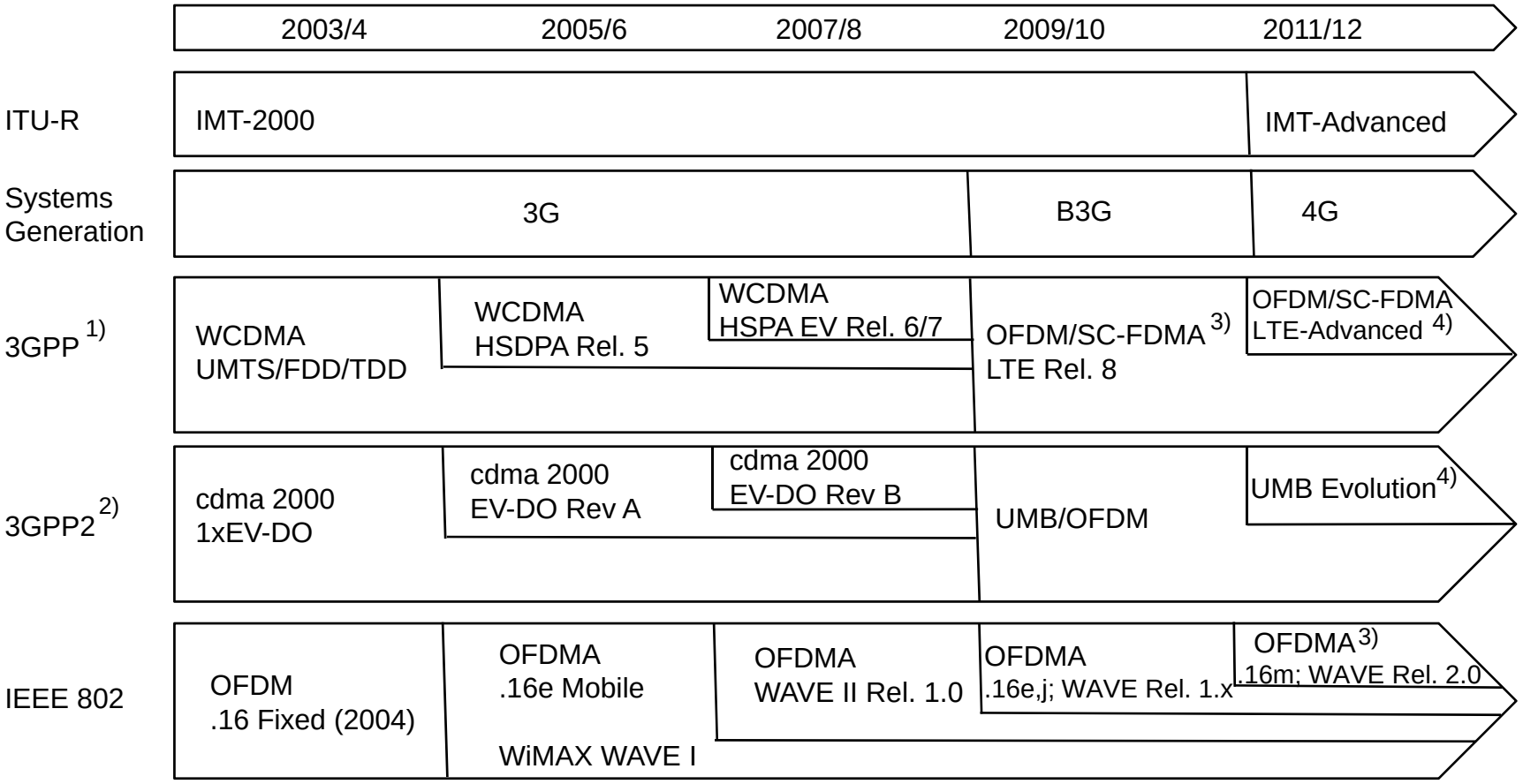
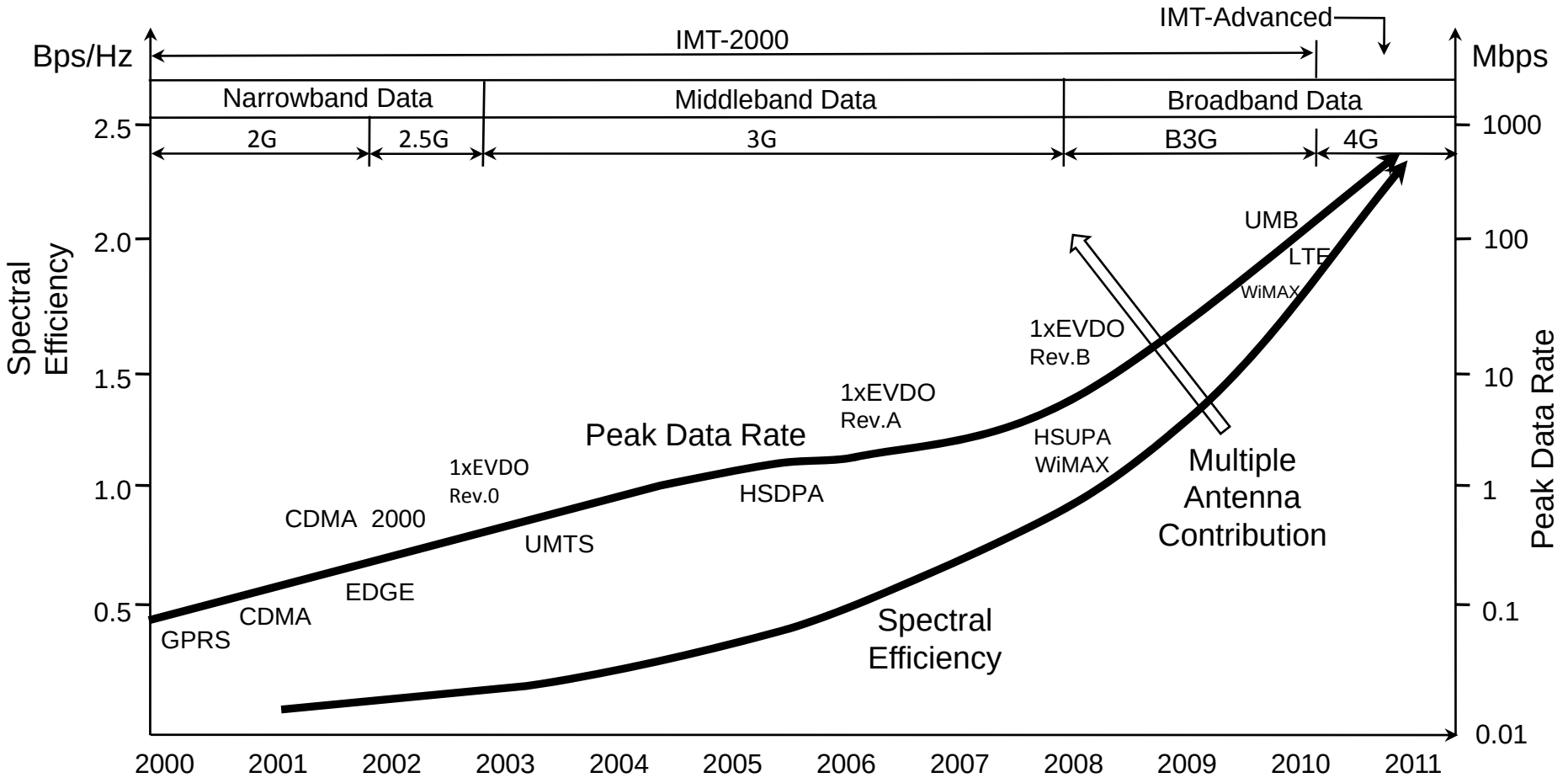
Roadmap of IMT–Advanced Candidate Systems



1) Overlay to GSM; 2) Overlay to CDMA-1x; (currently in question) 3) expected, but not specified, so far; 4) non-official name;

Source: Takagi/Walke: Spectrum Requirements Planning in Wireless Communications, J. Wiley 2008

Spectral Efficiency and Peak Data Rate Evolution in Time



Source: Takagi/Walke: Spectrum Requirements Planning in Wireless Communications, J. Wiley 2008

IMT-Advanced Candidate Systems

- 3GPP-LTE II / LTE + / LTE-Advanced
- Ultra Mobile Broadband (UMB) 3GPP2 /QUALCOMM (possibly: no system proposal)
- SUPER 3G (Japan)
- 3G+ (Korea)
- TD-SCDMA Ev. (China)
- IEEE 802.16m (based on 802.16e, j)
- IEEE 802.11n (ad-hoc component for cellular)
- WINNER+ (Europe) → LTE-Advanced

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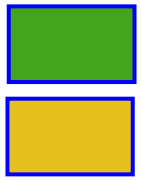
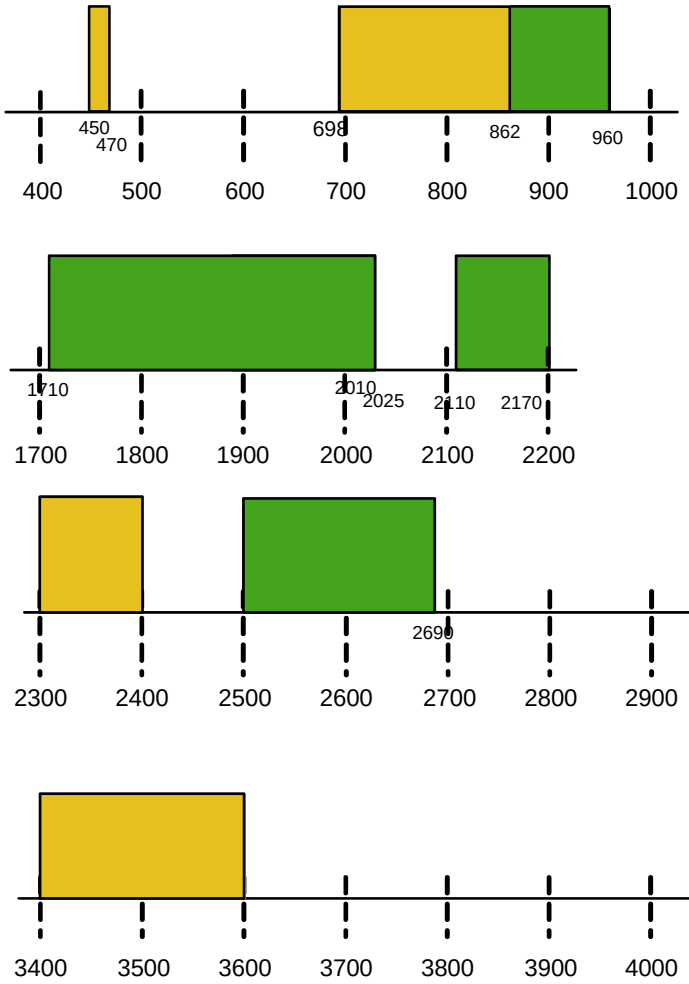
Bands identified by WRC-07 for IMT Systems

- WRC-07 identified new spectrum for IMT
- Changed IMT-2000 spectrum identifications to IMT
- Work has started on spectrum utilization



Previous IMT-2000

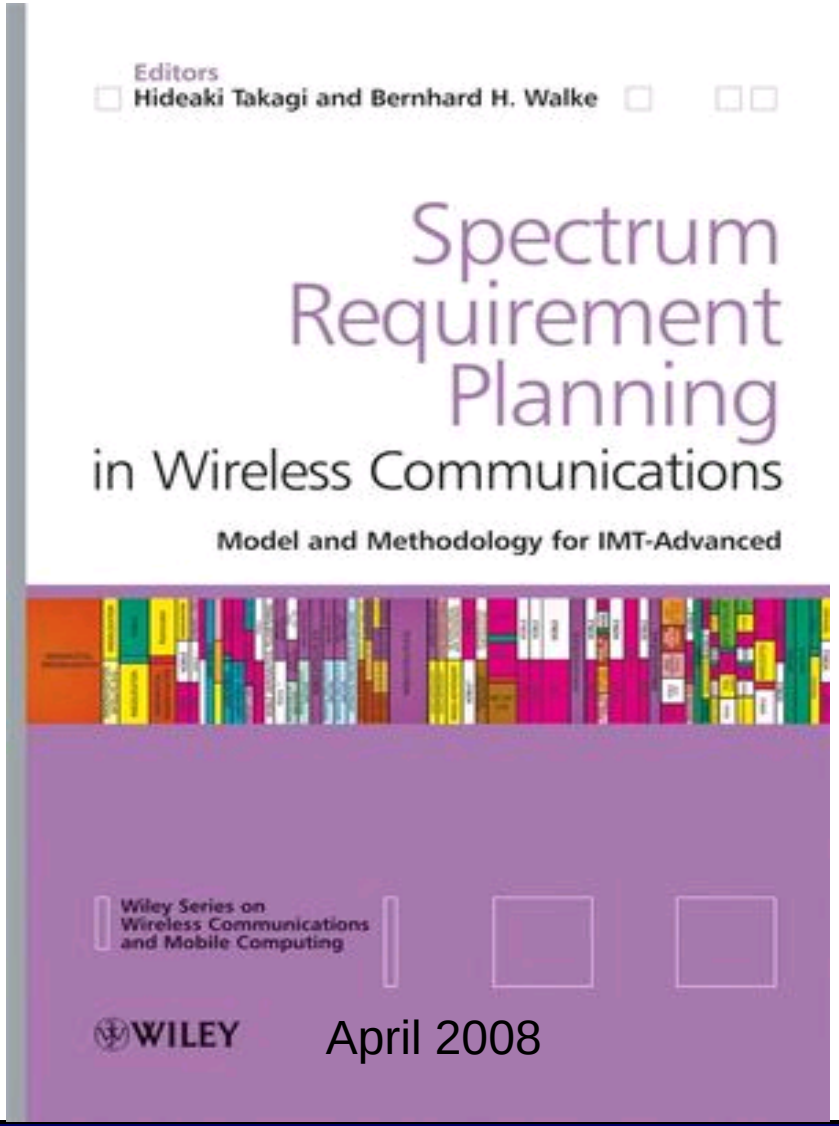
Identified at WRC'07



Simplified diagram!

Spectrum Requirements Calculation

- ITU-R M.1036 "Spectrum Estimation Methodology for IMT-Advanced Systems": 450 MHz needed. 464 MHz identified by WRC-07 in Nov. 2007



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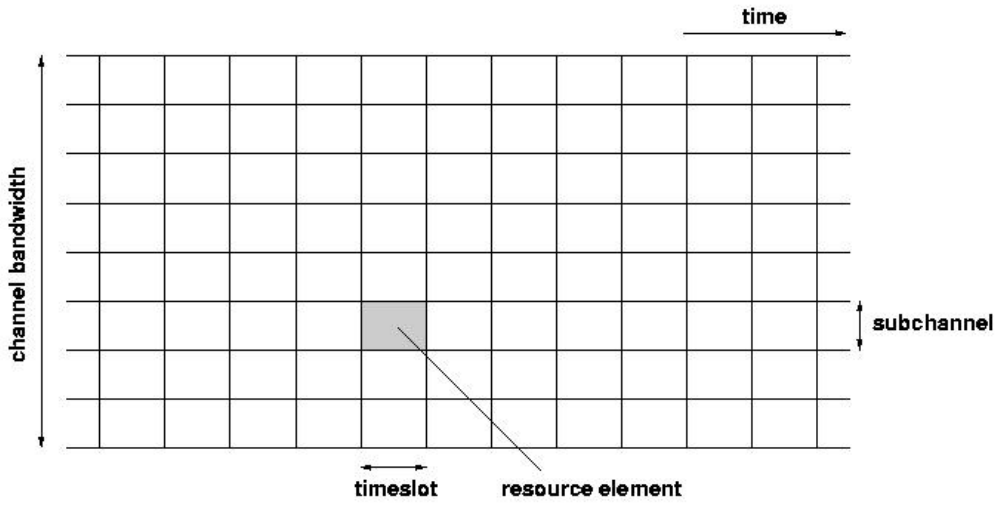
Main Characteristics of IMT-Advanced Systems

- **Orthogonal Frequency Division Multiplex (OFDM) to share the medium**
- **Orthogonal Frequency Division Multiple Access (OFDMA) for medium access**
- **Periodic MAC frame (known from RACE Project MBS and BMBF Project ATMmobil)**
- **Antenna Arrays at Base and Mobile Terminal**
- **Interference**
  - Coordination / Cancellation / Avoidance
- **Relay Enhanced Cells (known from Project IST-WINNER**
- **Simplified Network Operation (Radio Access Router enhanced by mobility support)**

OFDMA Subchannels and Resource Elements

- Transmission capacity as a Matrix
- Allocation of orthogonal Resource Elements possible
- Multi dimensional REs
  - Time, Frequency
  - Code, Space
- Constraints
  - Parallel transmission/ reception on different subchannels not possible
- Medium access control (MAC) is based on REs

  → optimal size of REs?



2-dimensional resource grid (time/frequency)

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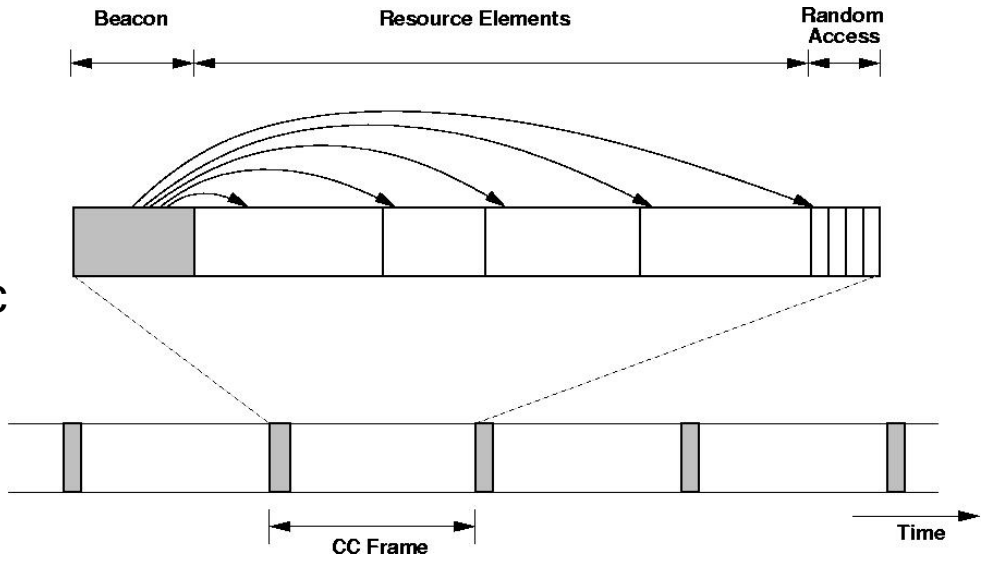
Medium Access Control (MAC) by central Base Station

MAC concept

- Centralized resource request/grant scheme
- Used in IEEE 802.16 (2004), proposed for IEEE 802.11n

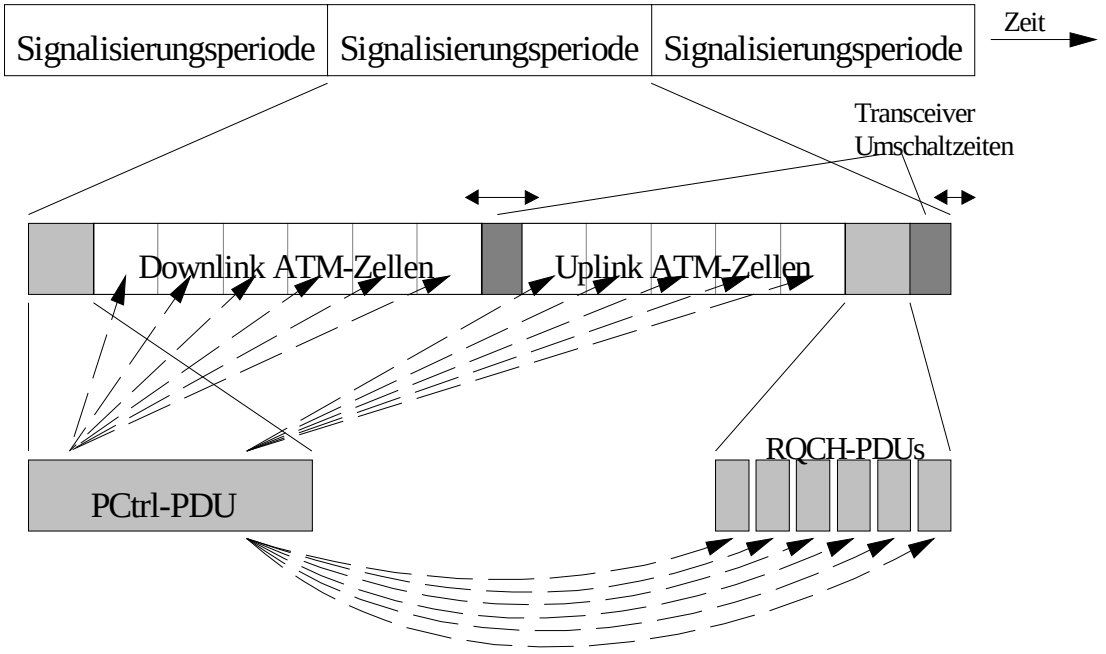
Frame structure

- Beacon (Broadcast)
  - Announcement of Resourc Elements
- Random Access Channel
  - Association, resource requests, ACKs
- Resource Element
  - Transmission of data burst (PDU train)



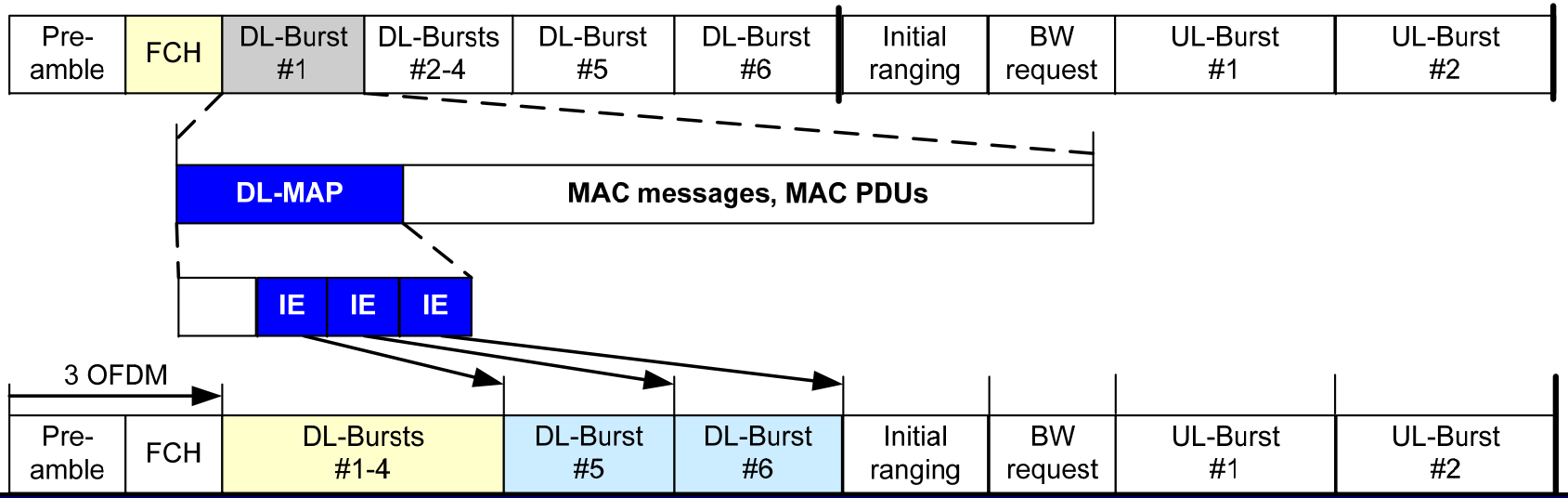
BMBF / ATM*mobil MAC-Protokoll wurde Std. ETSI / BRAN HiperLAN2*

- DSA++ Protokoll: ComNets Patent Walke/Petras 1995
  - Dynamische zentrale Kapazitätszuweisung auf *Slot* Basis
  - Rahmenbasiert, variable MAC Rahmenlänge
  - Unterstützung unterschiedlicher Dienstgüteanforderungen

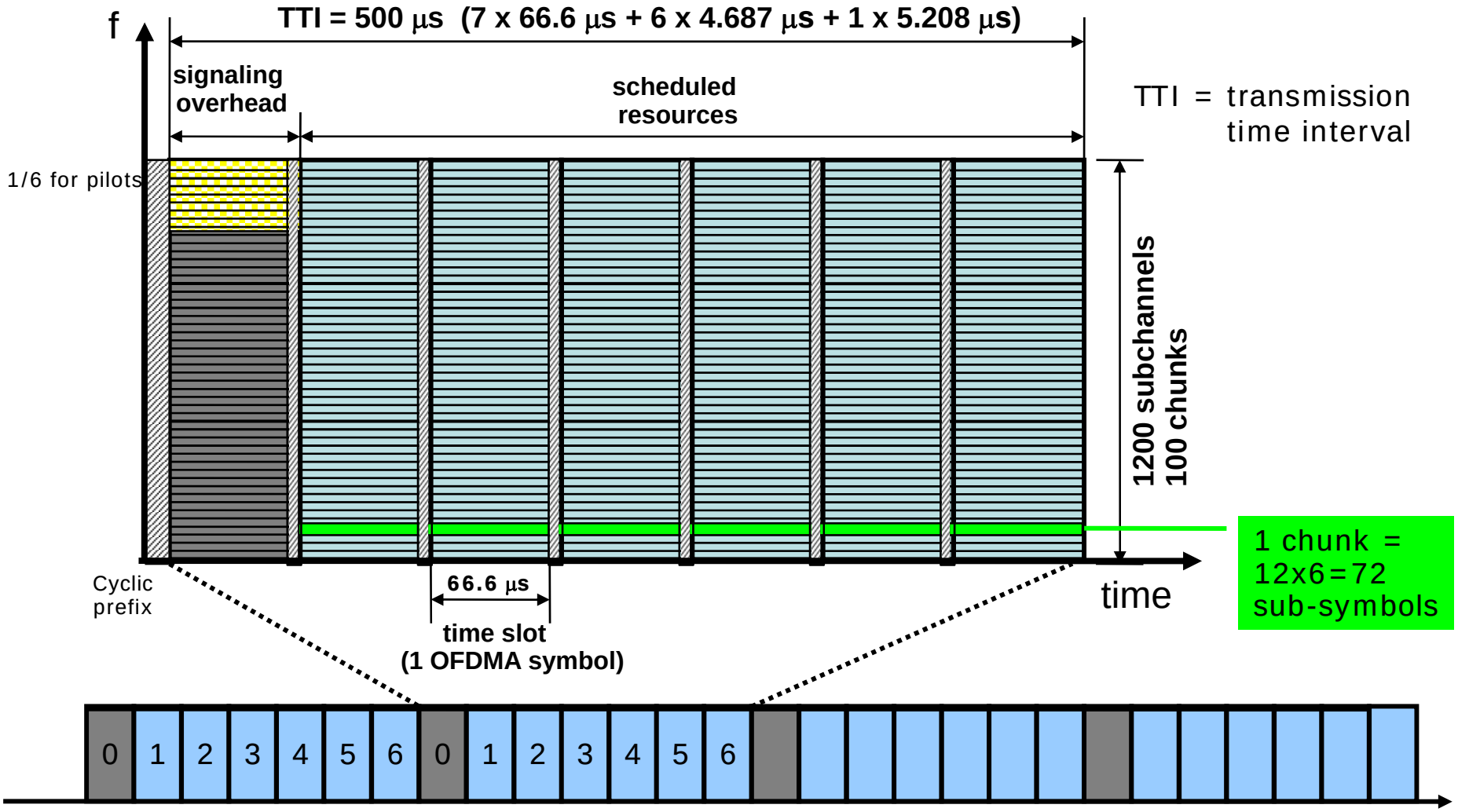


WiMAX MAC Protocol is identical to ETSI/BRAN/HiperMAN, that is derived from HiperLAN2

- Periodic MAC frame, starting with Frame Control Header (FCH)
- Contention phase (initial access, bandwidth request)
- Uplink (UL) and downlink (DL) phase
- Phases consist of burst
- Maps describing frame schedule
  - Downlink: Which station should receive the burst
  - Uplink: Which station is allowed to send in the burst



LTE TTI Frame (MAC Frame)
Further developed DSA++ protocol for OFDMA systems



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Cell Capacity vs. Distance is Inverse to the Needs

Range of broadband base station is limited
- high attenuation at high frequencies
- limited transmit power (EIRP limits)
- Unfavourable radio propagation conditions, e.g., in urban area

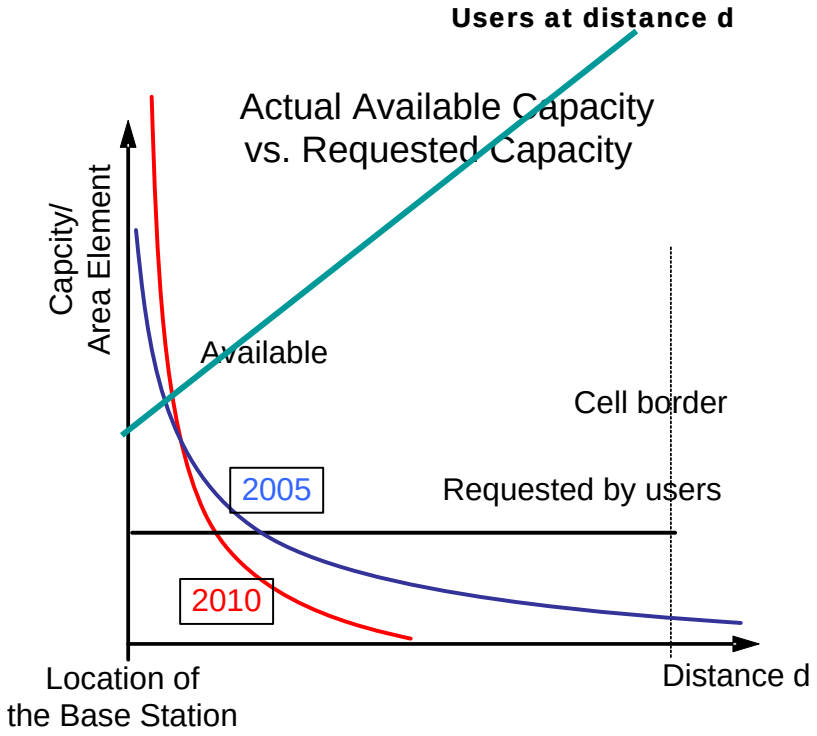
➔ # of BS required increases with increased carrier frequency to cover given area

➔ High Capital and Operations Expenses

➔ High cost/bit transmitted

➔ High data rate available close to AP only

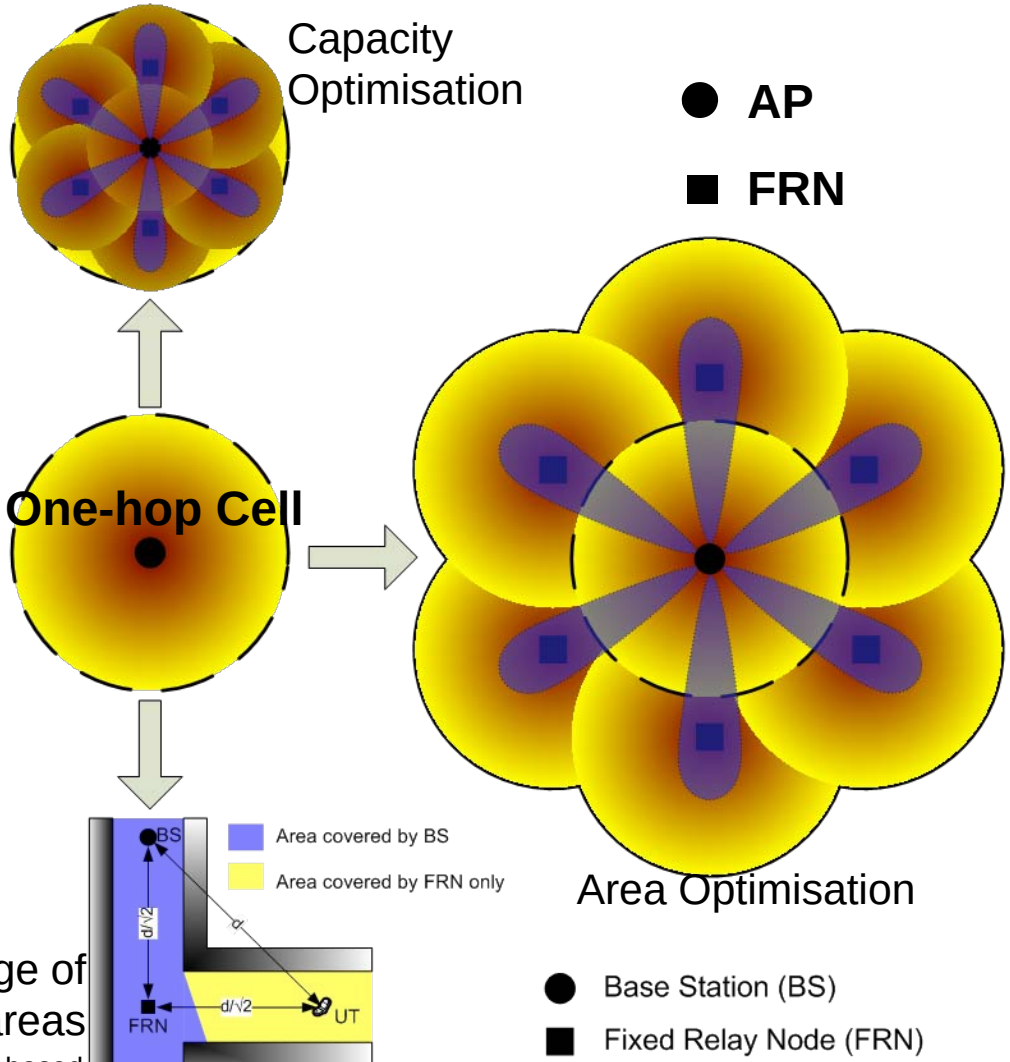
Under constant user density:
- o Number of users proportional to distance *d* from Base Station
- o Cell capacity per area element differs from what is requested by users
- o Technology trend worsens situation



Sources:
B. Walke, H. Wijaya, D.C. Schultz: Relays in Infrastructure-based Future Mobile Radio Networks, VTC 2006 Spring, Melbourne, Australia
T. Irnich, D.C. Schultz, R. Pabst, P. Wienert: *Capacity of a Relaying Infrastructure for Broadband Radio Coverage of Urban Areas. Proc. 10th WWRF meeting, New York*, 10/2003

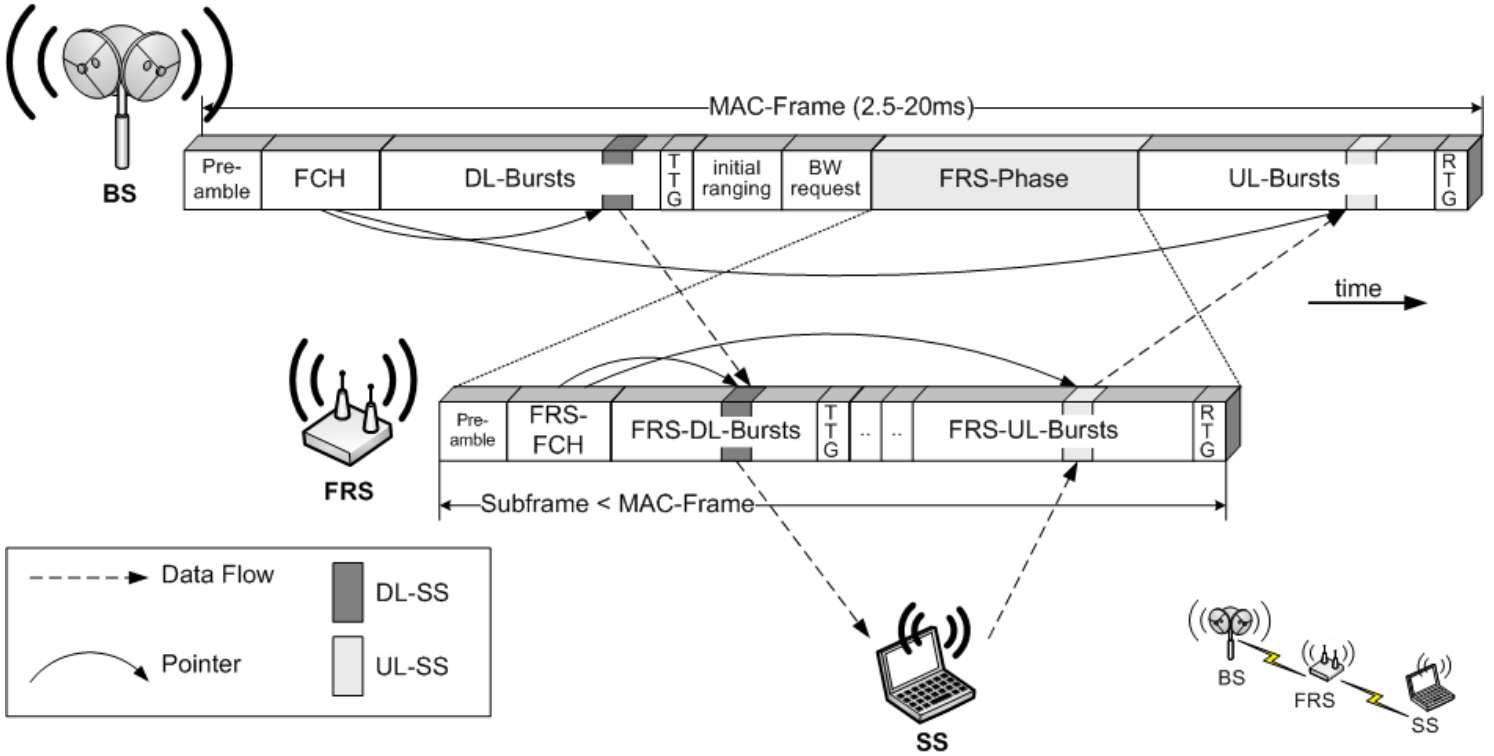
Relay Enhanced Cell (REC)
A cell complemented by Fixed Relay Nodes (FRN)

- Layer-2 Relays in REC
  - Save cost for wired backbone access
  - Full flexibility of relays positioning
  - enlarge the coverage area
  - Increase capacity at cell border
  - balance capacity/area element
  - reduce transmission power / co-channel interference
- Relays
  - Support fast network rollout
  - Allow outdoor to indoor service
  - Serve shadowed areas in REC
  - Exploit macro diversity
  - will be mass products



Source: B. Walke, H. Wijaya, D. Schultz: Relays in Infrastructure-based Future Mobile Radio Networks. VTC 2006 Spring, Melbourne, Australia

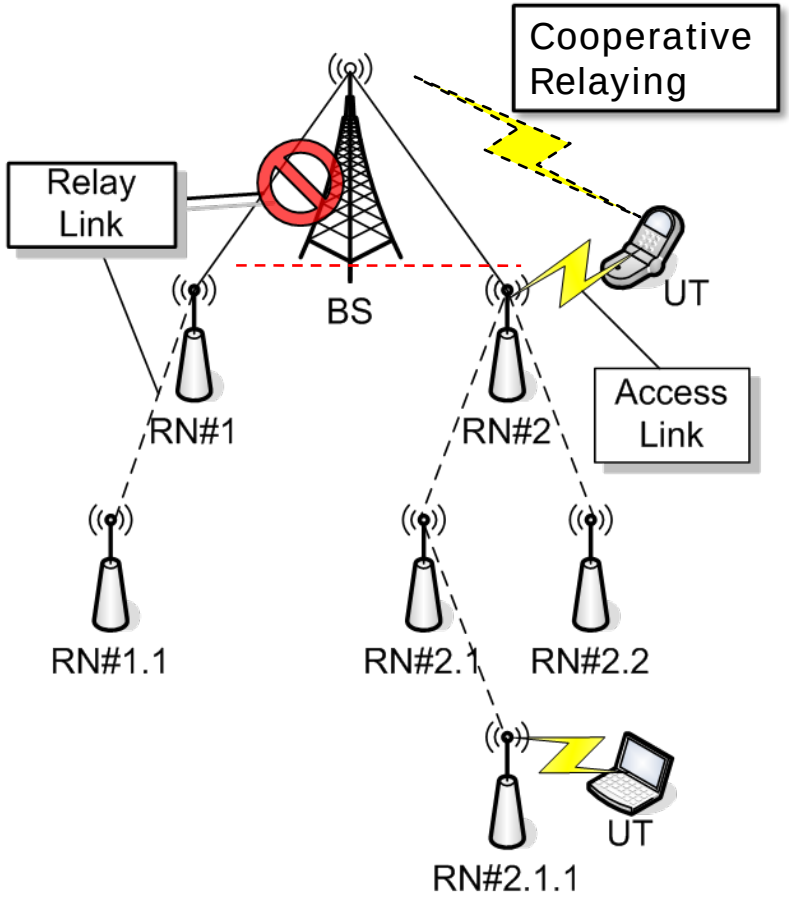
Relaying in Time Domain – Subframe Concept
ComNets Patent Walke/Esseling 2000



- Subframe Concept: Enables multi-hop operation for relaying in time domain
- Multiple FRS's are served by one BS
- FRSs' MAC frame are embedded to BS's MAC frame
- Duration of FRS MAC frame may depend on traffic load

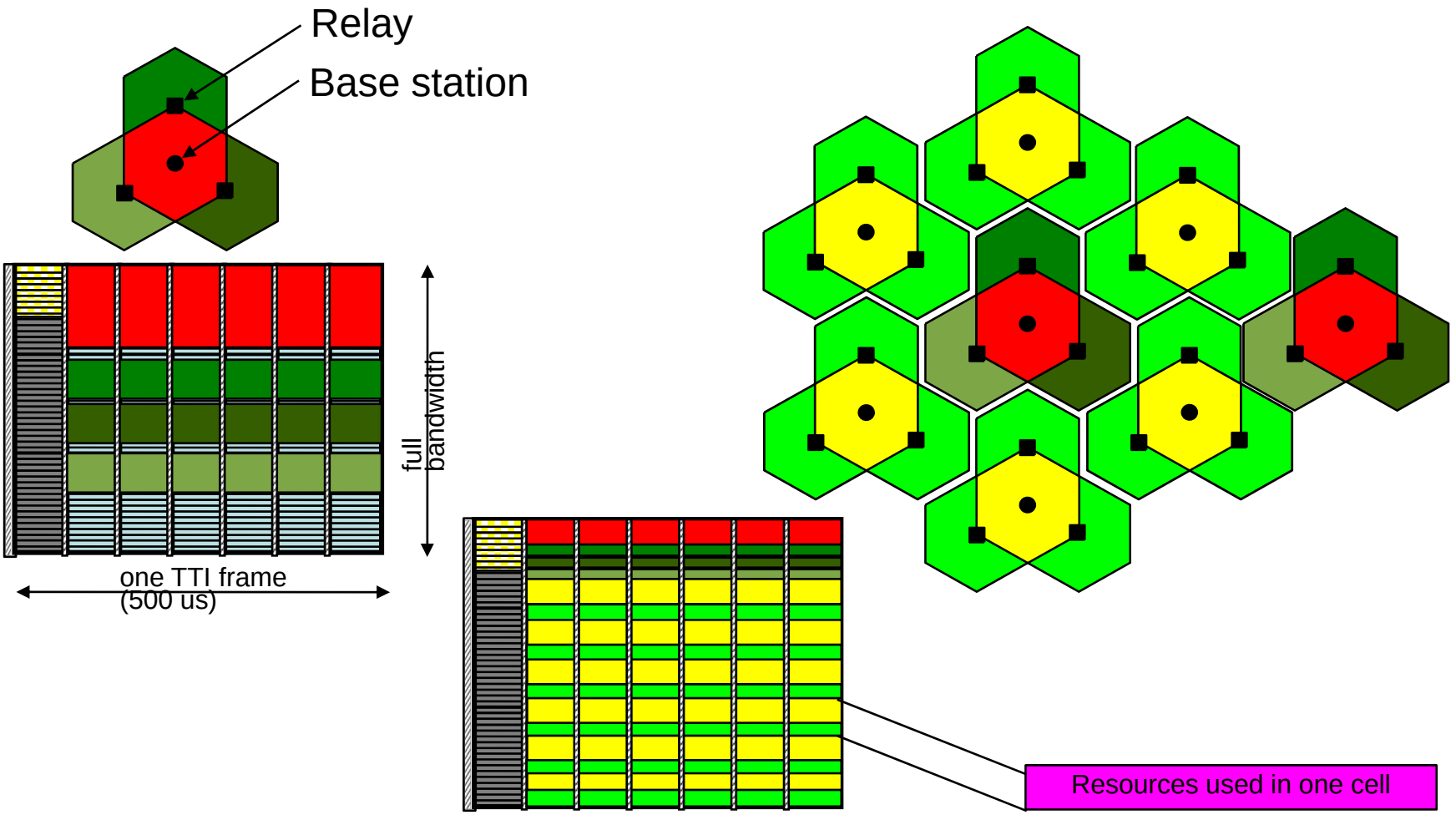
Layer-2 Relays in IMT-Advanced

- Layer 2 (Decode-and-Forward) relays are part of an IMT-Advanced systems, as specified by WINNER II
- Relay enhanced RRM technologies
  - Relays and multi-antenna technologies
  - Different modulation and coding schemes on relay and access link
  - Plug and play network roll out
- Tree topology, self-configuring nodes
  - Self healing: On demand re-organisation of the network topology
  - On demand meshing within REC
- Cooperative relaying as an option for capacity improvement



Multihop Network: Treetopology

Inter/intra Cell Resource Management
Resource Separation in Frequency Domain(OFDMA)



Mobile Broadband Networks will base on Relay Enhanced Cells

Conclusion

- IMT-Advanced spectrum allocated
- IMT-Advanced Systems
  - OFDMA: resources in time, frequency and space
  - Coordination needed: intra- and inter-cell
- Standardization in progress
- Relay enhanced cells are part of it (IEEE802.16j)
  - extend cell range
  - increase throughput at cell edge
  - Reduce impact of signal shadowing
- Relays save Telco infrastructure cost

Thank you!

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