3G Evolution – HSPA and LTE for Mobile Broadband

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Mobile Broadband

HSPA

Turbo-3G

LTE

Maxis Broadband

More Than 400* HSPA Devices!

- 203 HSPA phones, media players, camera (50%)
- 161 PC with embedded HSPA, PC cards, USB modems (40%)
- 39 wireless routers (10%)

*Commercially launched as of August 2007

So…what is HSPA and LTE?

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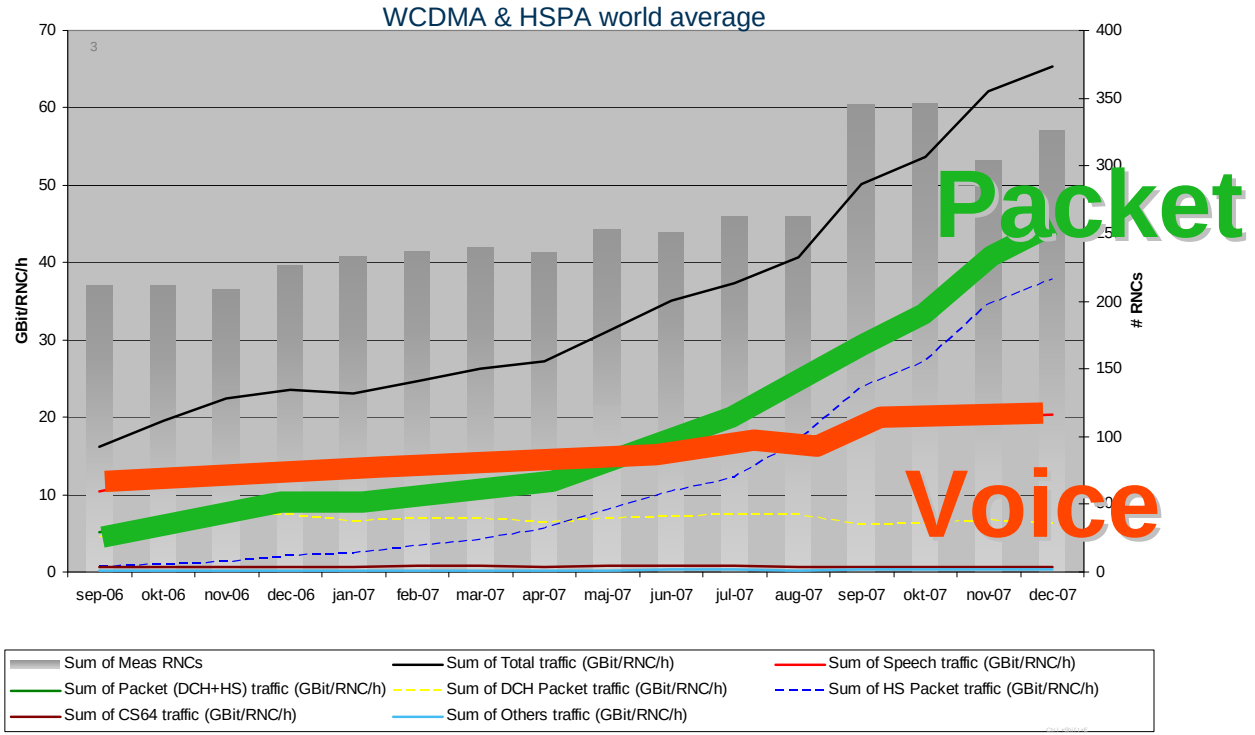
Trend – Data is overtaking Voice

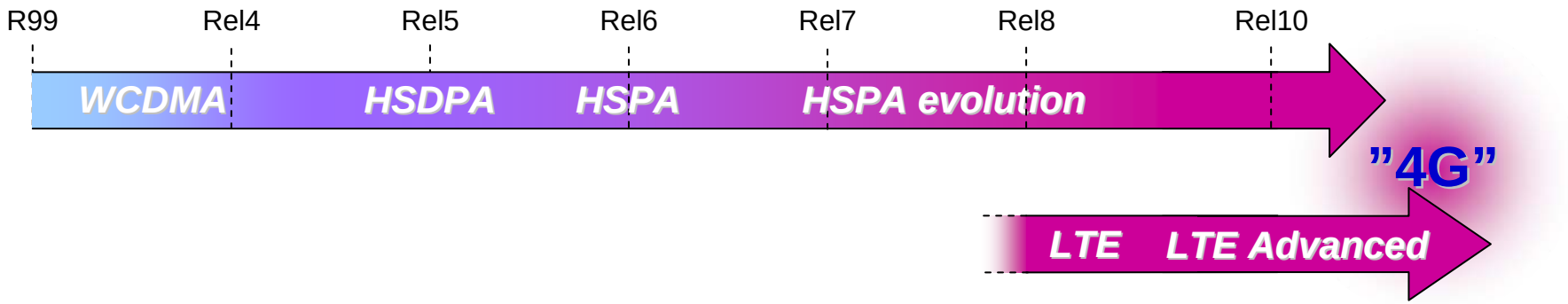
- Data is overtaking voice...
  ...but previs cellular systems designed primarily for voice



Source: NetQB

HSPA and LTE = Mobile Broadband

- HSPA – *High-Speed Packet Access*
  - Evolution of 3G/WCDMA
  - Gradually improved performance at a low additional cost
  - Data rates up to ~20 Mbit/s *in 5 MHz*



- LTE – *Long-Term Evolution*
  - Significantly improved performance *in a wide range of spectrum allocations*
  - Data rates up to ~300 Mbit/s in 20 MHz
  - First step towards IMT-Advanced (”4G”)

Different systems – but many basic principles are similar!

Wireless vs Wireline

- Wireless seems simple…

$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

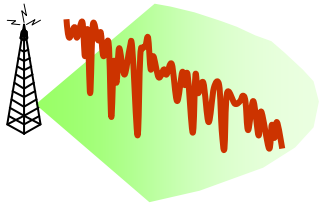
$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

- …so what's the problem?

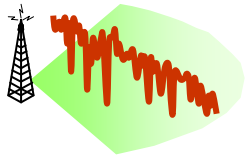
Radio Channels and Packet Data

- Radio channel quality varies...
  - ...distance to base station
  - ... random variations in the environment
- Traffic pattern varies...
  - ...user behavior
  - ...server load

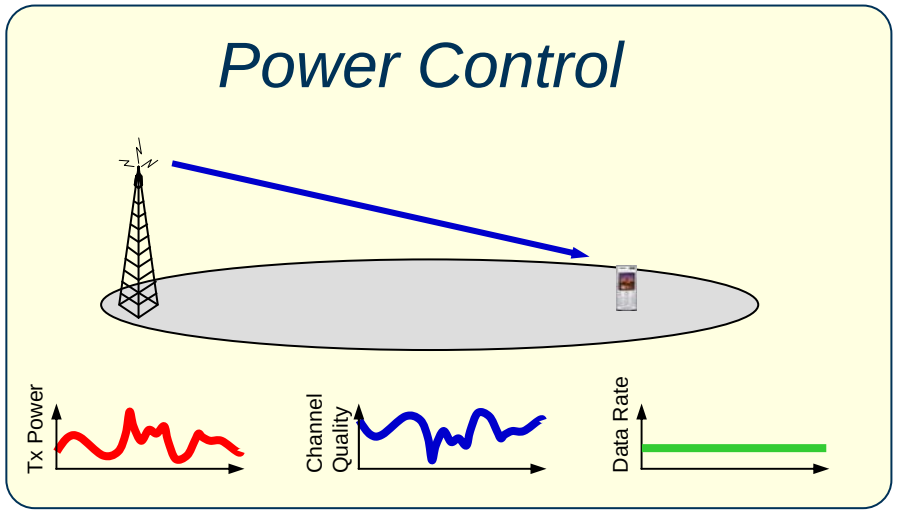


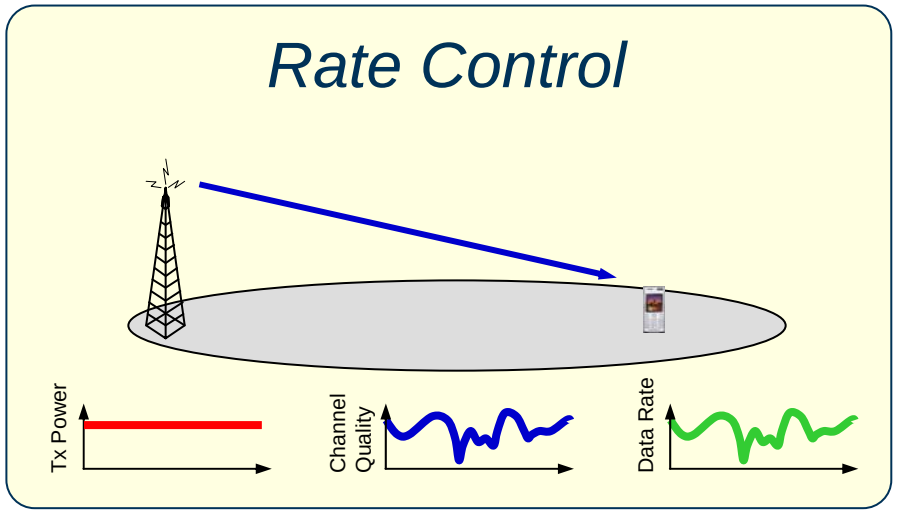
Adapt to and *exploit* channel and traffic variations!

Rate Control



- Reliable reception requires a certain E_b/N_0
- How to control E_b?
  - $E_b = P \bullet T$

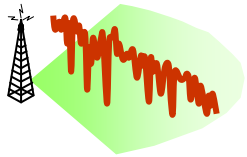




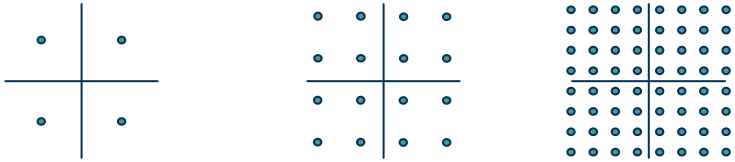
- Varying instantaneous data rate acceptable for packet-data services
  - Rapid – tracks fast fading

Rate control more efficient than power control!

Rate Control



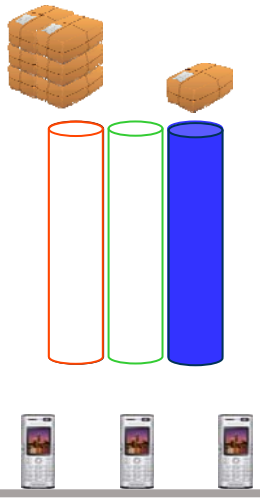
- Data rate controlled through...
- ...different channel coding rates
  - Advantageous channel conditions ➡ high code rate
  - Code rates from 1/3 to ~1
- ...different modulation schemes
  - Advantageous channel conditions ➡ higher-order modulation

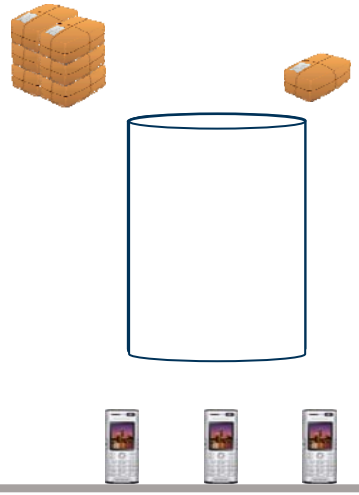


- ...different multi-antenna schemes

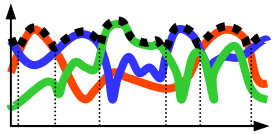
Shared-Channel Transmission

- Dedicated channel
  - User resources assigned at ”call setup”
  - Independent of instantaneous traffic situation
- Shared channel
  - Dynamic sharing of common rerouce
  - Adapts to instantaneous traffic situation



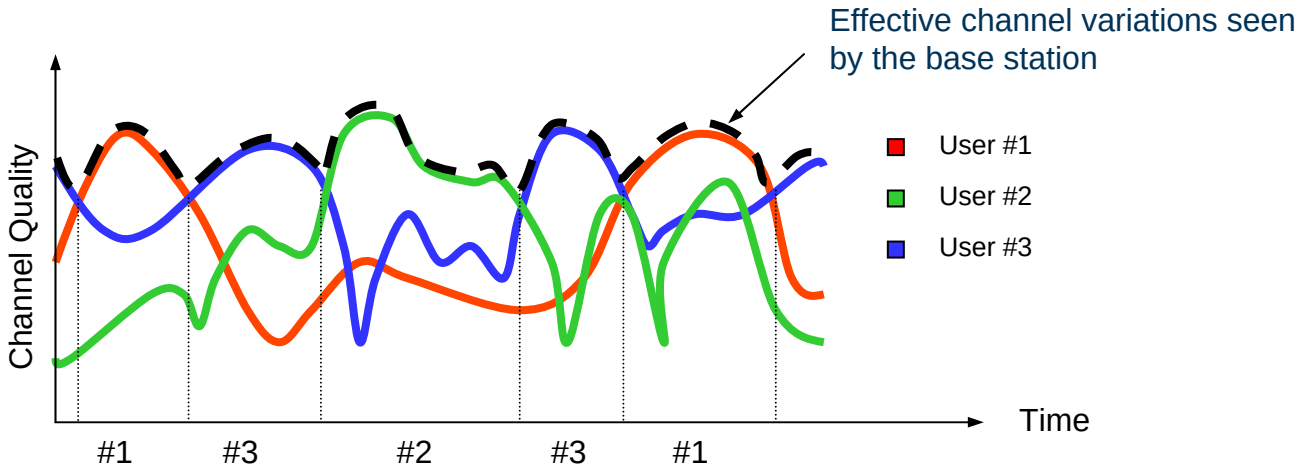


Channel-dependent Scheduling

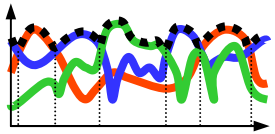


- Scheduling determines at each time instant…
  - …to whom to assign the shared channel
  - …which data rate to use

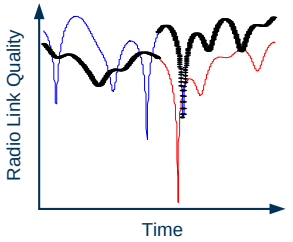
- Basic idea: transmit at fading peaks
  - May lead to large variations in data rate between users
  - Tradeoff: fairness vs cell throughput



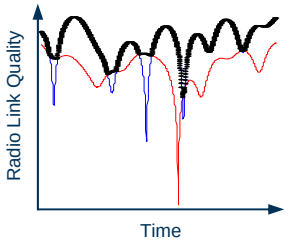
Channel-dependent Scheduling



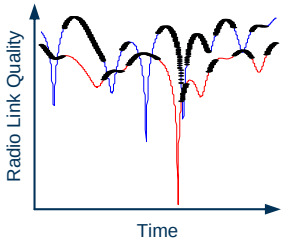
- Round Robin (RR)
  - Cyclically assign the channel to users without taking channel conditions into account
  - Simple but poor performance



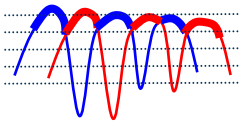
- Max C/I
  - Assign the channel to the user with the best channel quality
  - High system throughput but not fair



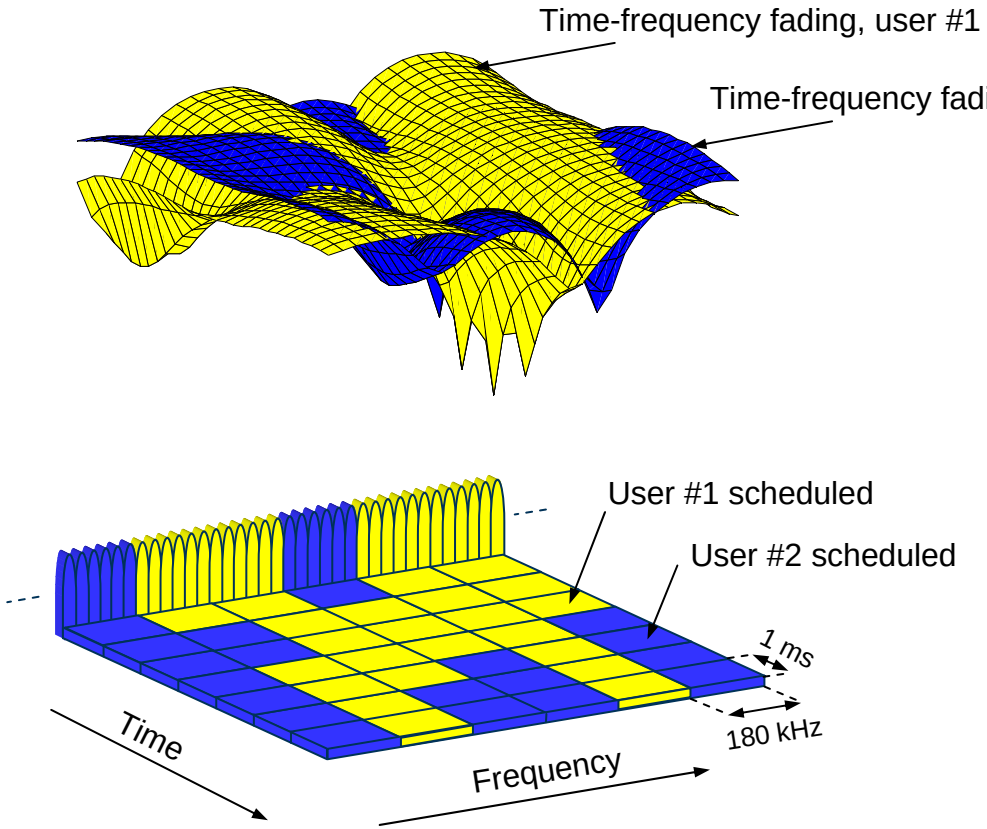
- Proportional Fair (PF)
  - Assign the channel to the user with the best relative channel quality
  - High throughput, fair



Channel-dependent Scheduling



- HSPA – channel-dependent scheduling in time-domain only
- LTE – channel-dependent scheduling in time *and* frequency domains



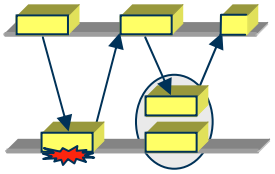
Channel Quality Indication

- Scheduling and rate control adapts to channel variations

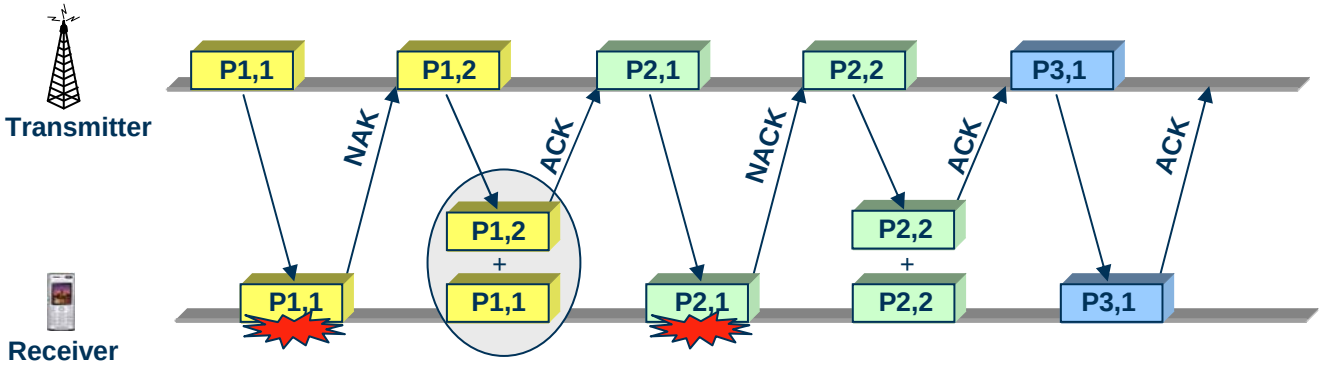
- Problem: need channel knowledge at the base station
- Solution: terminals transmit channel-quality reports to base station

- Reporting rate configurable
  - HSPA – reports as often as every 2 ms
  - LTE – reprots as often as every 1 ms

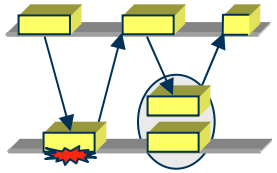
Hybrid ARQ with Soft Combining



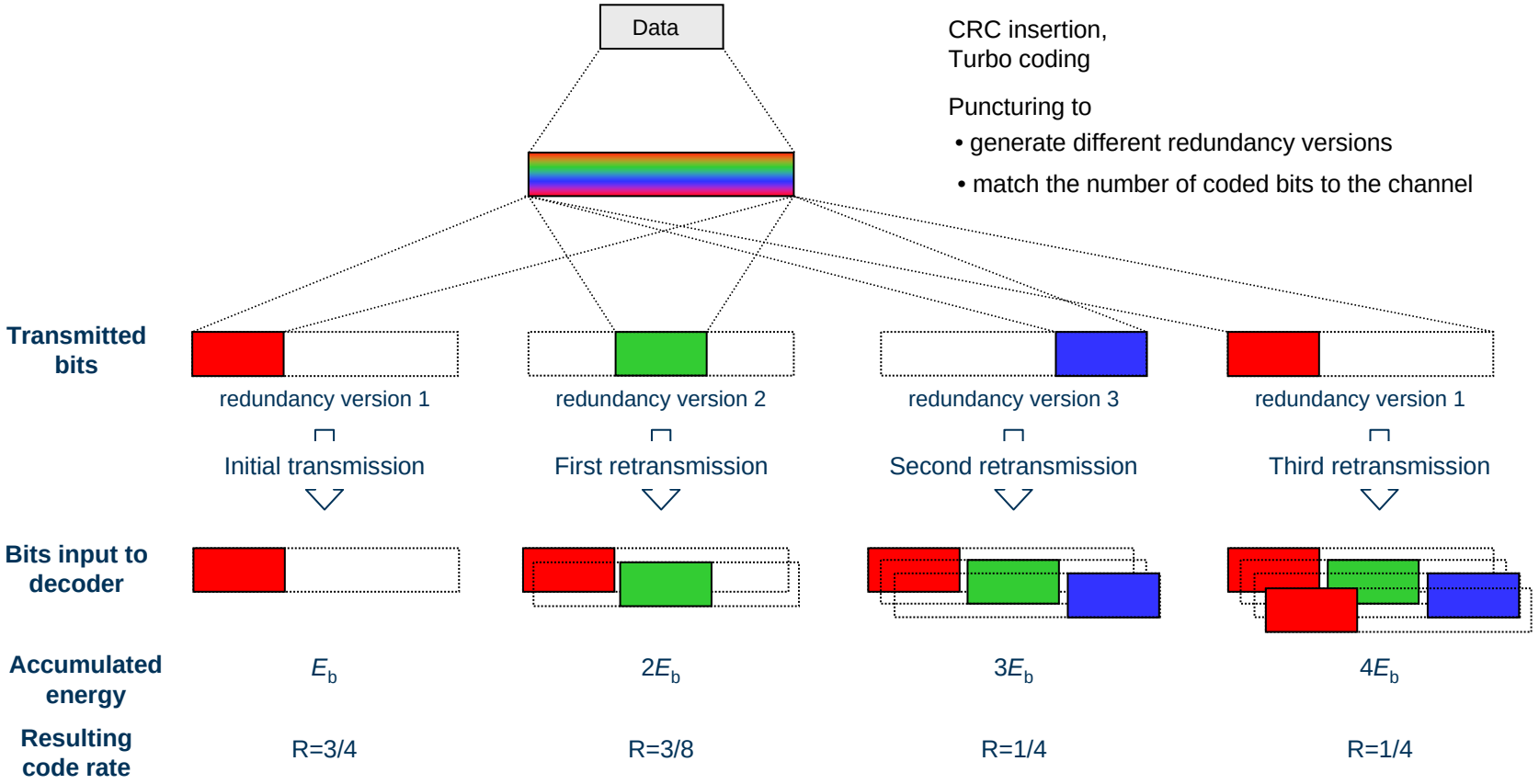
- Retransmsision of erroneously received packets
  - Fast ➡ no disturbance of TCP behavior
- Soft combining of multiple transmission attempts
  - Soft combining ➡ improved performance



Hybrid ARQ with Soft Combining

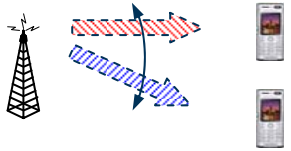


- Incremental redundancy

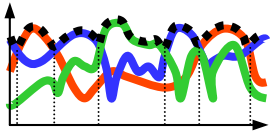


Basic Principles – Summary

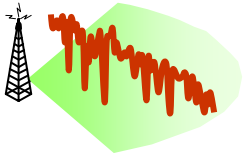
- Shared channel transmission



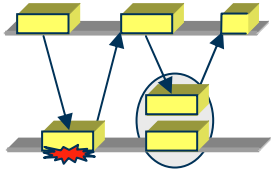
- Channel-dependent scheduling



- Rate control

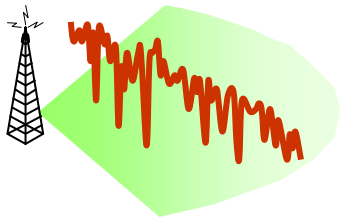


- Hybrid-ARQ with soft combining



Summary

- Radio channel quality is time varying



- Traffic pattern is time varying

- ***Adapt to*** and ***exploit***
  - variations in radio channel quality
  - variations in the traffic pattern

…instead of combating them!

Work in 3GPP

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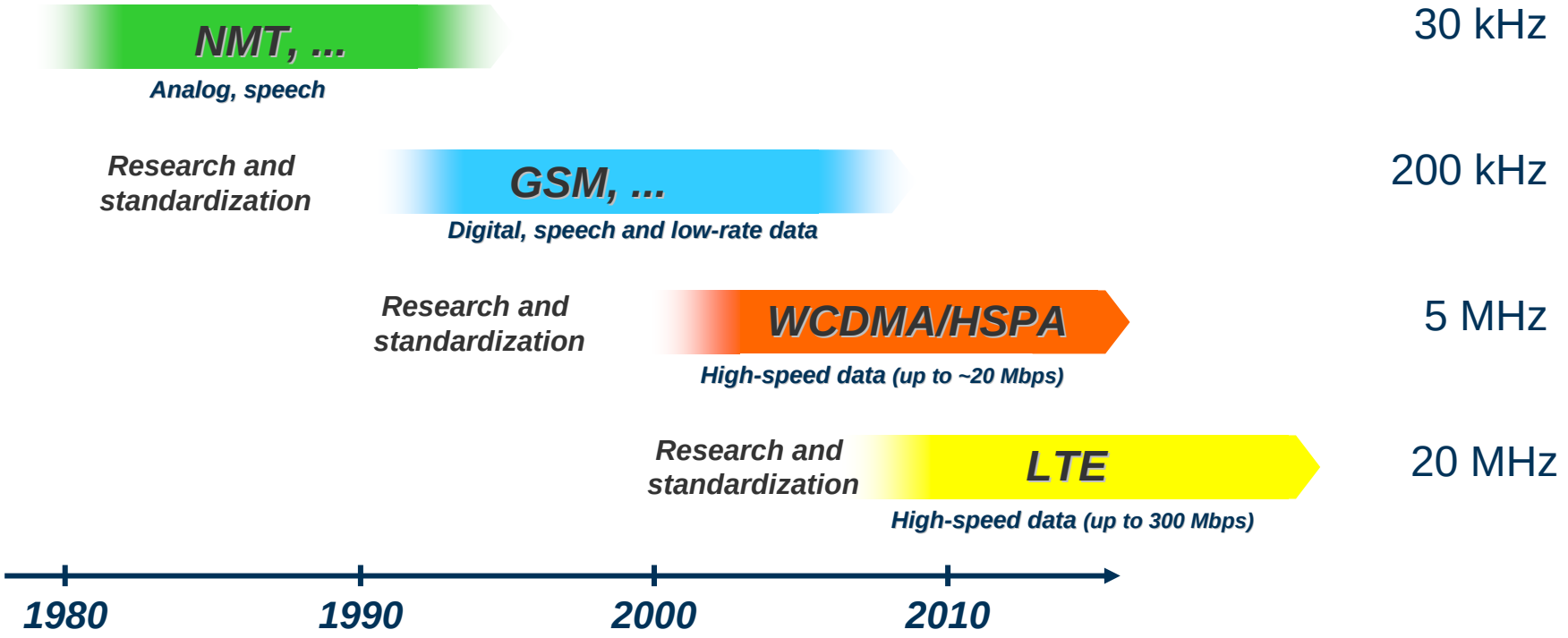
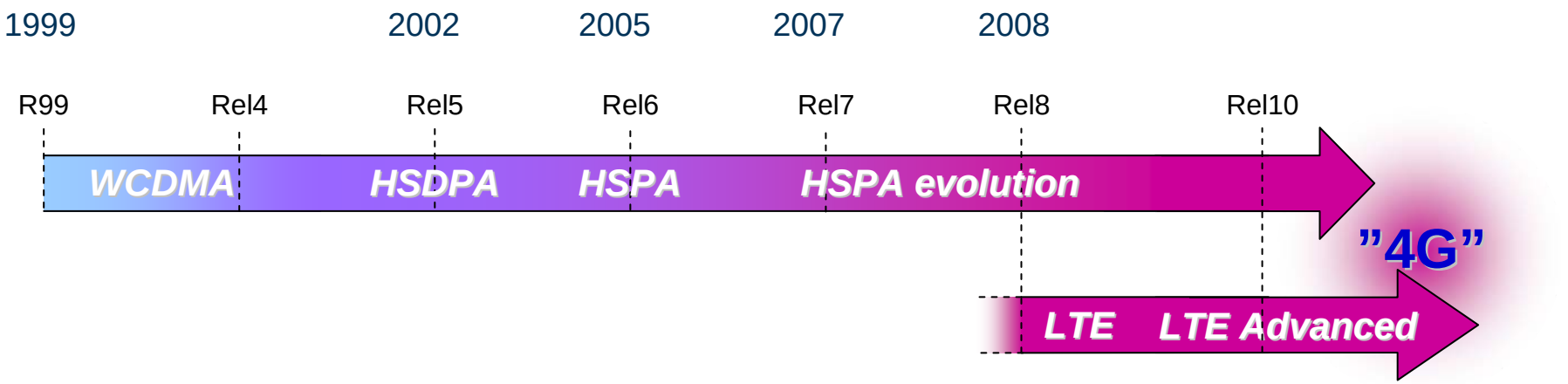
History


NMT, ...
Analog, speech
30 kHz
Research and standardization
GSM, ...
Digital, speech and low-rate data
200 kHz
Research and standardization
WCDMA/HSPA
High-speed data (up to ~20 Mbps)
5 MHz
Research and standardization
LTE
High-speed data (up to 300 Mbps)
20 MHz
1980
1990
2000
2010

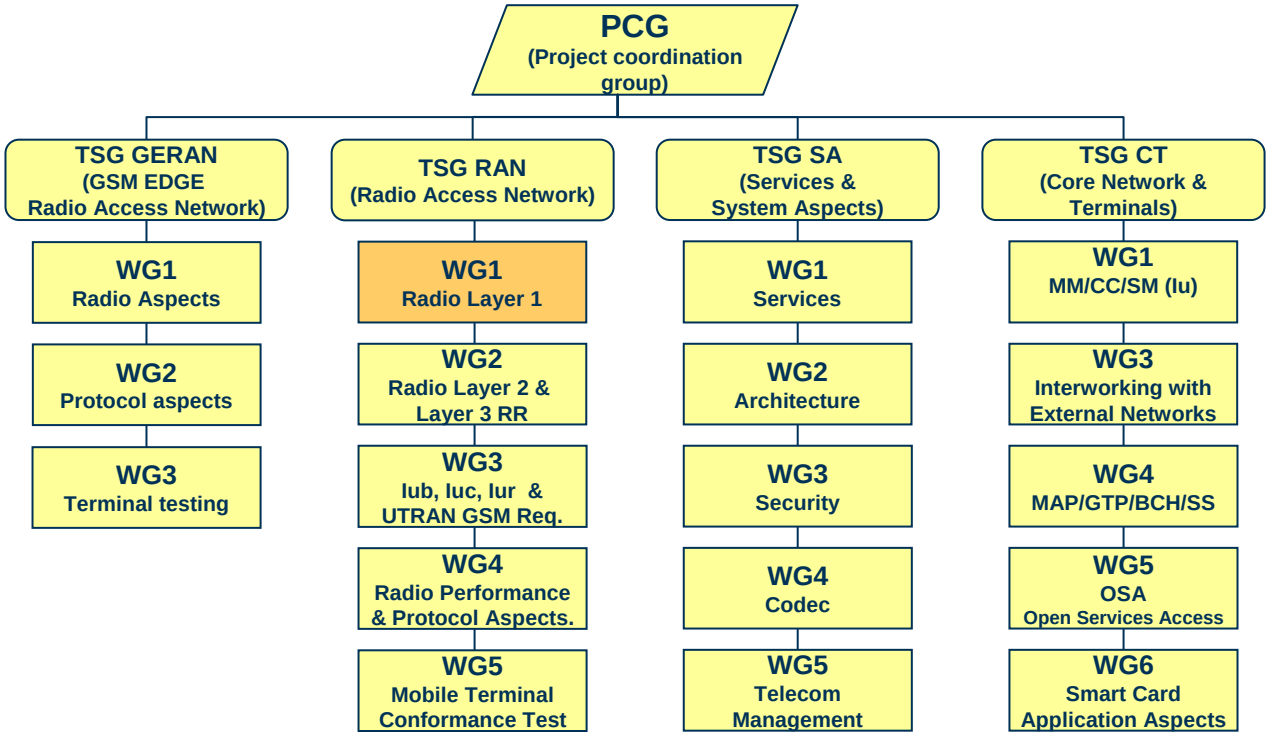
3G Evolution



- HSPA evolution
  - gradually improved performance at a low additional cost *in 5MHz spectrum allocation*
- LTE
  - significantly improved performance *in a wide range of spectrum allocations*
  - further evolved into *IMT-Advanced*

3GPP

- International organization
  - Vendors and operators co-operate
  - Develop specifications for GSM, WCDMA/HSPA, LTE



Standardization – a Flying Circus?

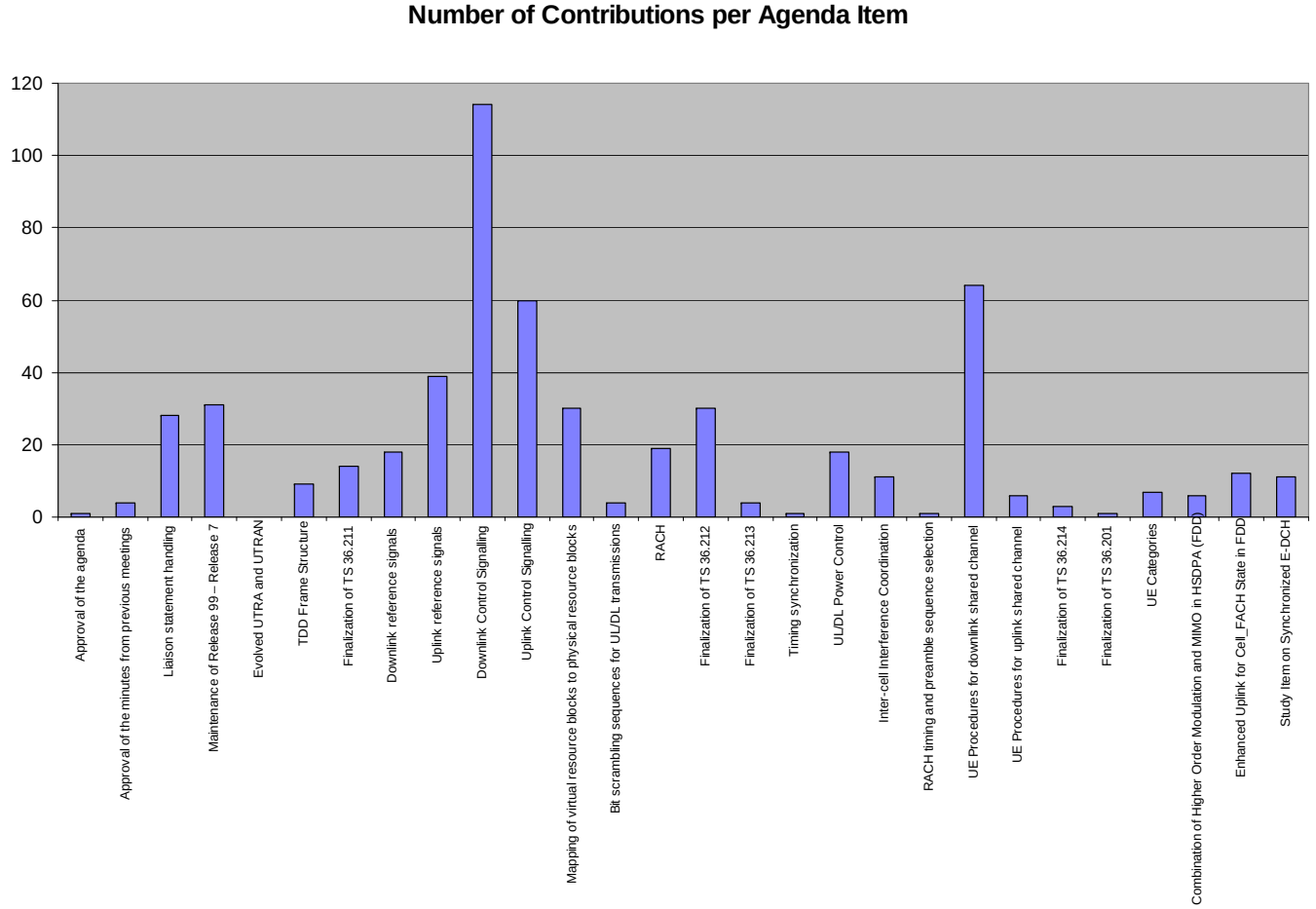
- RAN1 meetings held ~8 times a year
  - Meetings run from Monday to Friday
  - Held in various countries in Europe, North America, and Asia

- Meeting schedule 2007

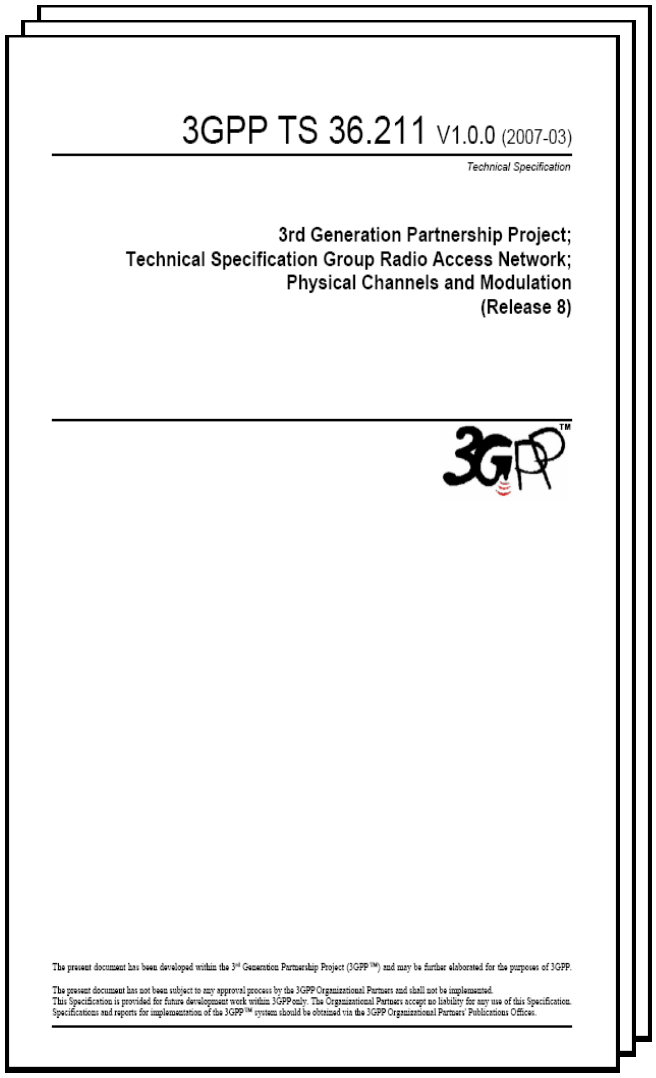
– January 15-19,	Sorrento,	Italy
– February 12-16,	St Louis,	USA
– March 26-30,	St Juliens,	Malta
– April 17-20,	Beijing,	China
– May 7-11,	Kobe,	Japan
– June 25-29,	Orlando,	USA
– August 20-24,	Athens,	Greece
– October 8-12,	Shanghai	China
– November 5-9,	Seoul	Korea

Typical RAN1 Meeting

- Approx 200 delegates attending and ~550 documents submitted...



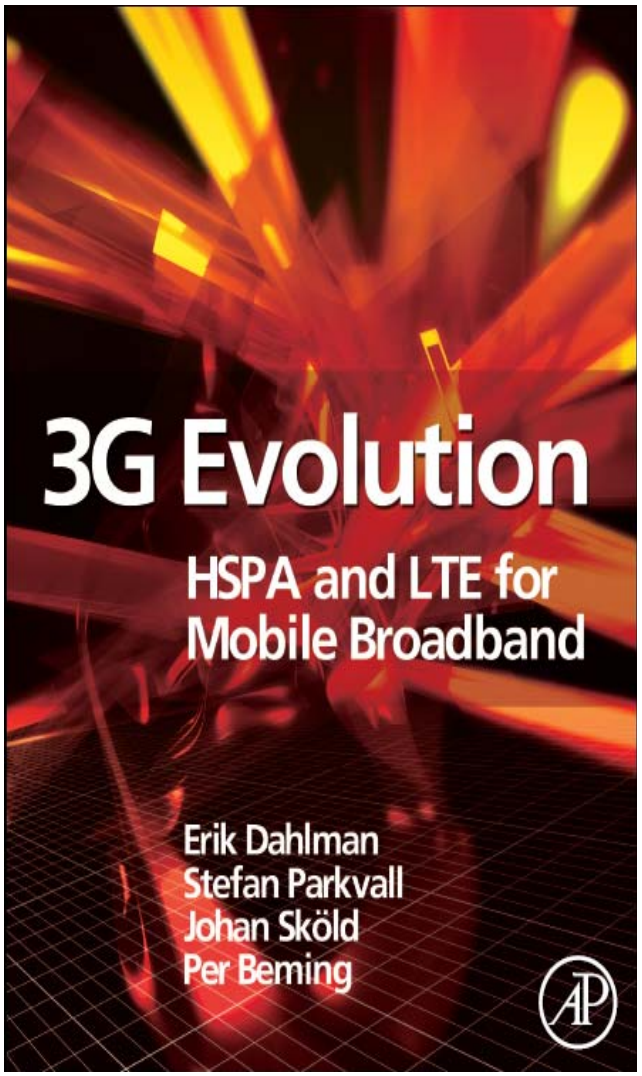
Taking You Forward...



3GPP TS 36.211 V1.0.0 (2007-03)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Physical Channels and Modulation
(Release 8)

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