network of the future: some challenges ahead

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Acknowledgements

This presentation is a radio and access-centric view of the challenges for the future networks. Very important issues with packet core and service layer evolution are not discussed.

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our vision: connect everyone and everything



mobile Internet





heterogeneous network

mobile, fixed, short range, personal

social networks





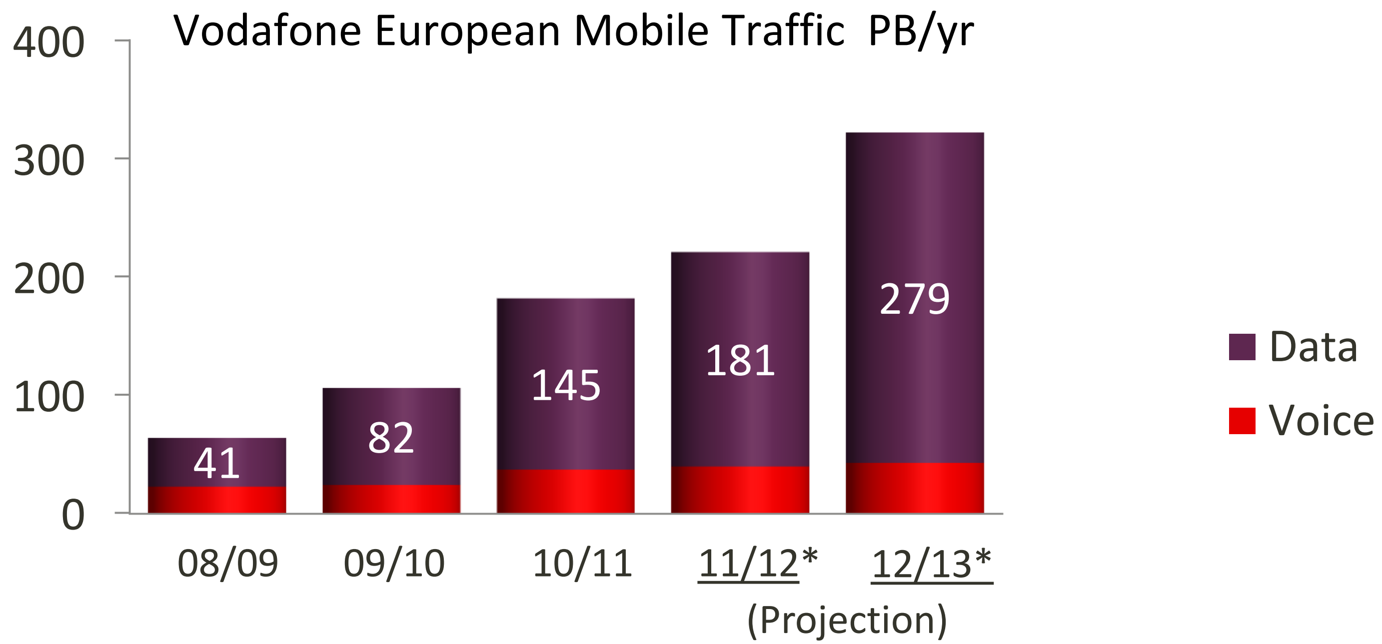
e-mobility

m-Health

m-governance

- ***provide seamless connectivity to all devices***
- ***hide complexity from end-user***
- ***broker services & create simple charging models***

status quo: update on traffic



- Moore's law for mobile data holding up (roughly doubling every two years)
- data roughly 5 times of voice traffic and 1/5th of revenue
- mobile video traffic more than half of total data traffic
- 4G users create an order of magnitude more usage on the network (Cisco study claims x28)

ways to increase mobile cellular capacity

	future potential
Link spectrum efficiency	*near limit*
system spectrum efficiency	*great potential, but challenging*
more spectrum	*only in higher frequencies*
smaller cells	*almost unlimited potential, but expensive*

system spectrum efficiency : potential

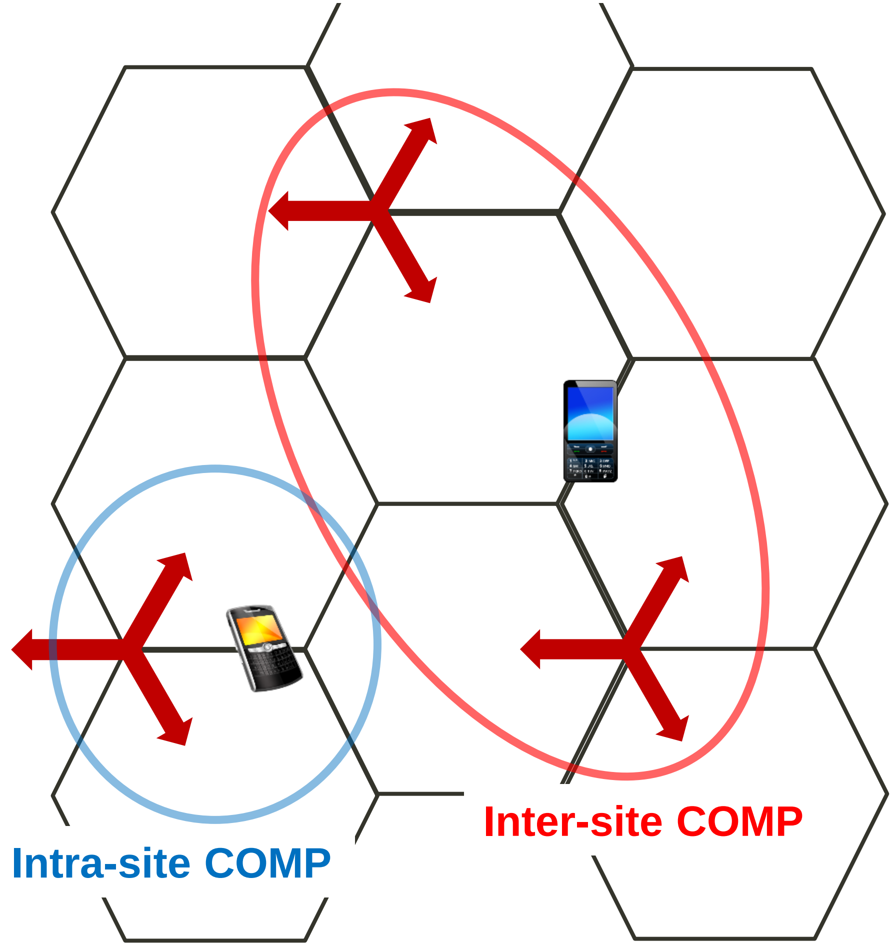
system spectrum efficiency

- information theory suggests that vast improvements can be made by eliminating all inter-cell interference
- many practical constraints limit gains (mainly on system-wide channel estimation)
- results so far achieved are modest – particularly on downlink (30%)
- we are far from theoretical limit (bounded only by Shannon capacity)
- theoretical limit for a fully cooperative network:

$$C_{cell} \sim \log(1 + N\mathrm{SNR})$$

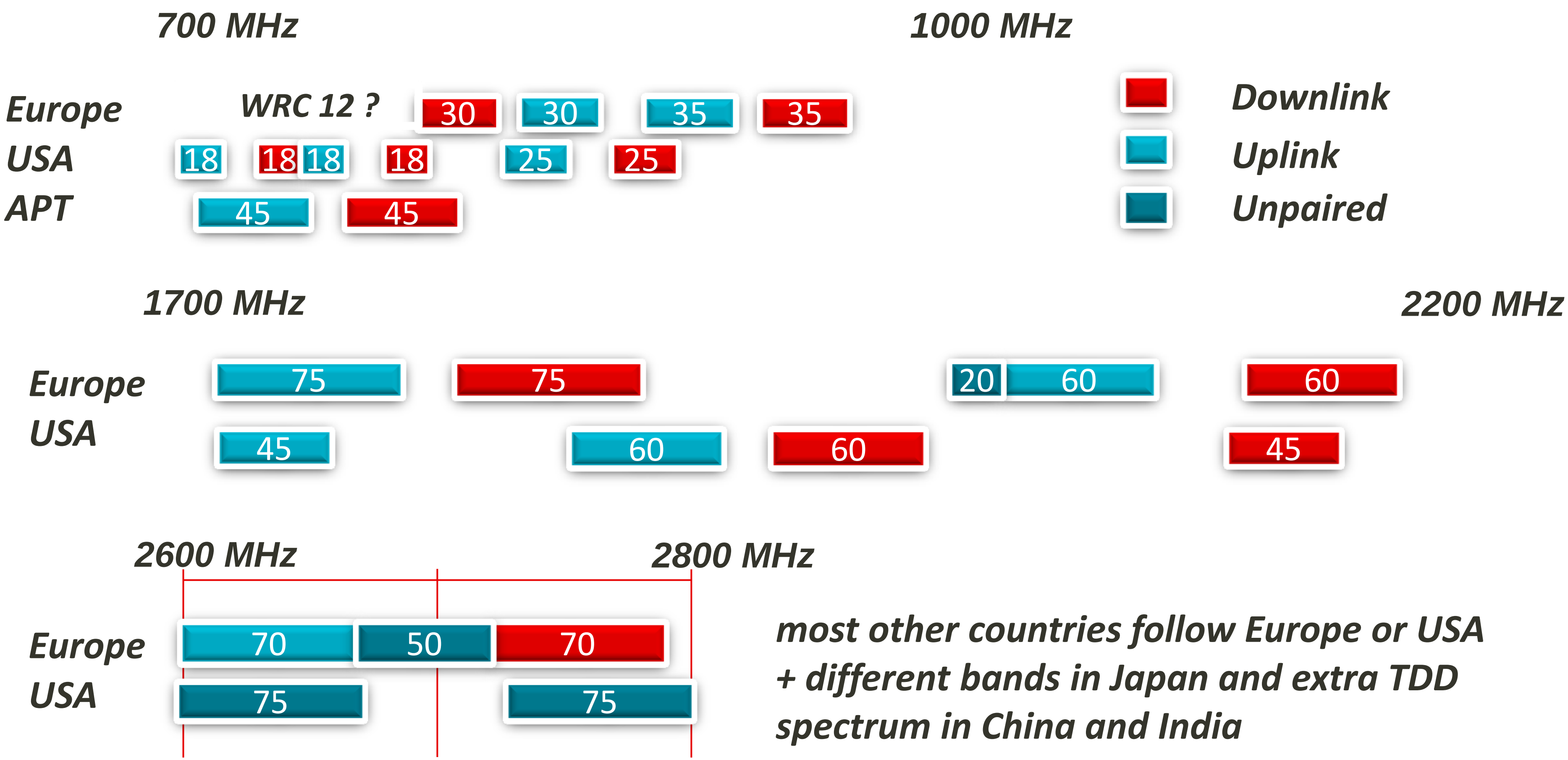
where N is the number of users

coordinated multi-point transmission/reception (COMP)



global mobile licensed spectrum is fragmented & scarce

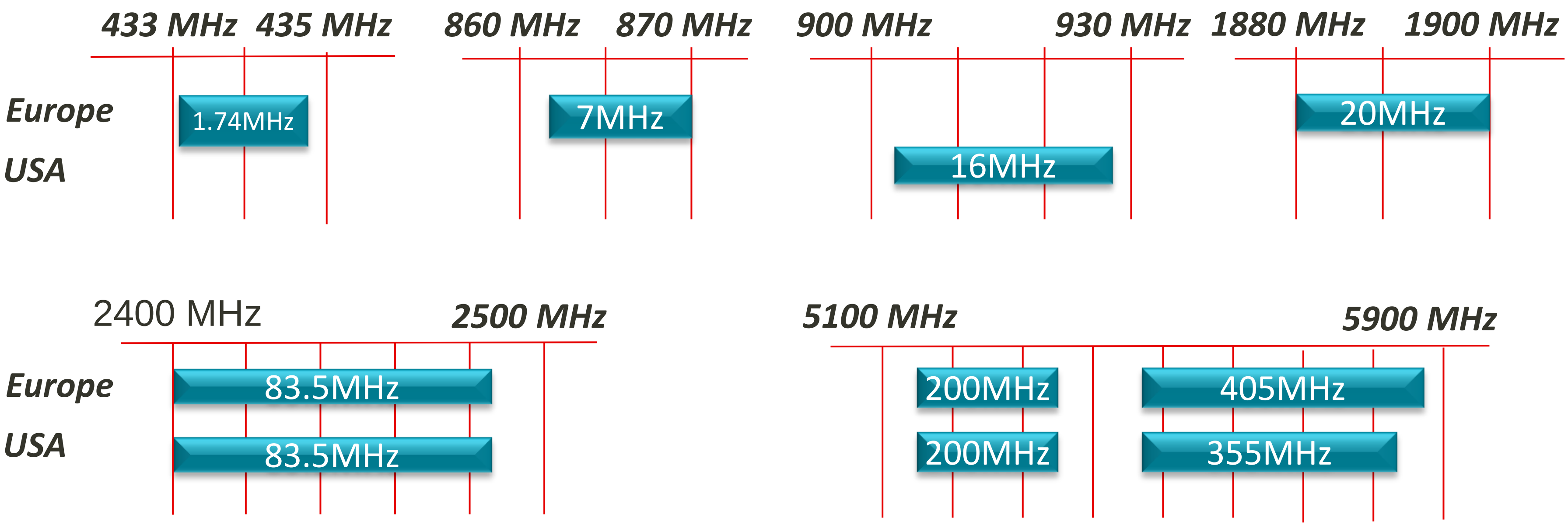
more spectrum

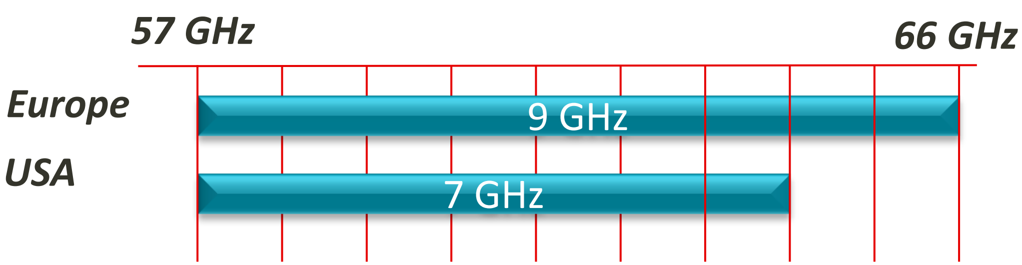


most other countries follow Europe or USA + different bands in Japan and extra TDD spectrum in China and India

roughly 580 Billion MHz pops of licensed spectrum in Europe & USA

unlicensed spectrum: Europe & USA





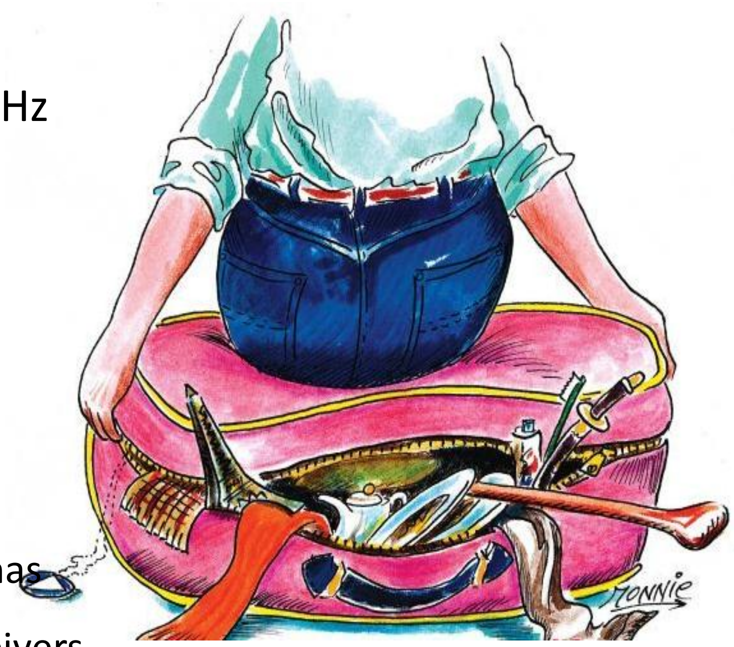
countries vary and some parts of bands are reserved for specific purposes or have specific technical restrictions. Unlicensed does not mean free-for-all

roughly 9500 Billion MHz pops of unlicensed spectrum in Europe & USA

the multi-band radio dilemma

more spectrum

- today – 5 band / 2 standard devices are common
  - typically GSM / 3G, 850, 900, 1800, 1900, 2100 MHz
- many new bands considered:
  - **33** different bands identified in 3GPP LTE specifications!
  - realistically ~**15** for an “almost global” terminal
- plus GPS, WiFi, Bluetooth, FM radio, DAB,….?
- MIMO adds at least a doubling of receive chain and antennas
- cross-band spectrum aggregation could need more transceivers
- WRC-15 agenda items will be looking for more!
- “SDR” is delivering on multi-standard support, **but RF is a big challenge**



how do we support all these bands?

device RF performance dilemma

more spectrum

terminal cost

network cost

1dB loss in RF performance = 14% more sites for same coverage

there is 5 dB variation between best & worst devices (twice the sites)

2 antennas in all terminals improve capacity by 40% and cell edge by 75%

LTE devices need more bands and must maintain performance (challenging)

RF performance restricts spectrum exploitation

more spectrum

FCC halts LightSquared rollout pending "targeted" GPS interference tests
Air Transport Intelligence news 13th September 2011

Nascent broadband provider LightSquared's plans to roll out a satellite-terrestrial network adjacent to the GPS band next year have been halted by the US Federal Communications Commission (FCC).

The problem:

coexistence with neighbours

will White Space solve spectrum shortage?

more spectrum

- "White Space" technology in UHF TV band is suggested as a solution to spectrum shortage

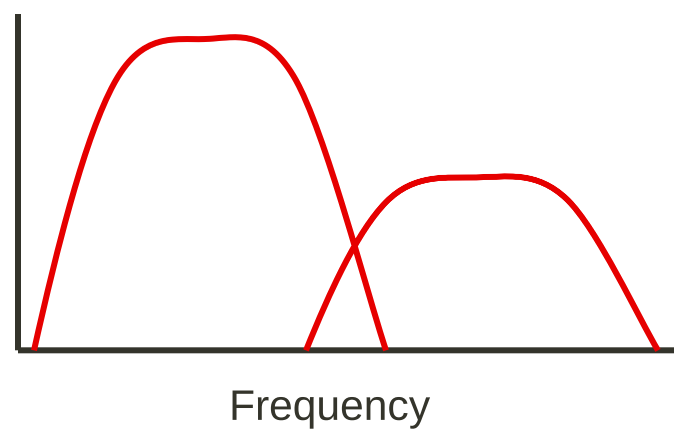
BUT

- beware: "Tragedy of the Commons"
- FCC rules in US require TX adjacent channel suppression of 72.8dB – much tighter than today's mobile phones
- TV receivers need to be improved too!
- there are big challenges of RF design in consumer devices

Ofcom plans "white space" networks by 2013

1 September 2011

UK Regulator Ofcom has published plans to use licence-free wireless frequencies to promote a wide range of new services and potentially push broadband further into rural areas.



the research challenge - we need radios that:

more spectrum

can tune anywhere

have efficient antennas

have clean transmitters

reject adjacent interference

have sensitive receivers

and are small and cheap!

areas for research in RF circuits

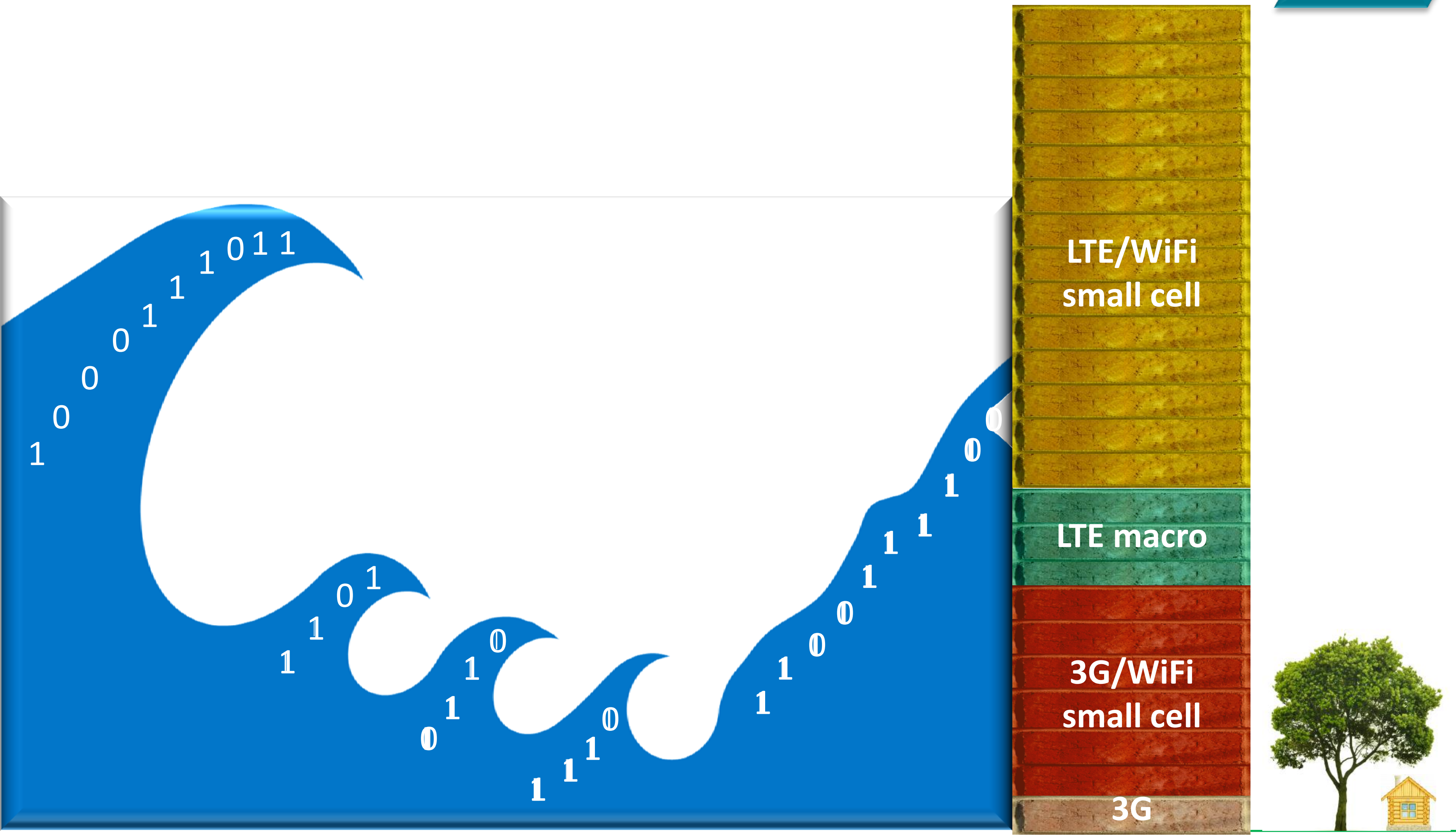
more spectrum

- some areas to consider:
  - low loss **switching** with high isolation
  - continued incremental improvement in **filter** performance at low cost
  - broadband **PAs** shared between adjacent bands
  - broadband **antennas** with adaptive tuning/ matching
  - technologies for **tunable RF filtering**
  - **digital correction** of analogue imperfections

continued major investment in RF R&D is needed to enable rapid growth of mobile internet (disruption badly needed)

handling the data tsunami

smaller cells



hierarchical and heterogeneous networks

smaller cells

GSM
GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS
3G
Lte

seamless authentication

continuous connectivity

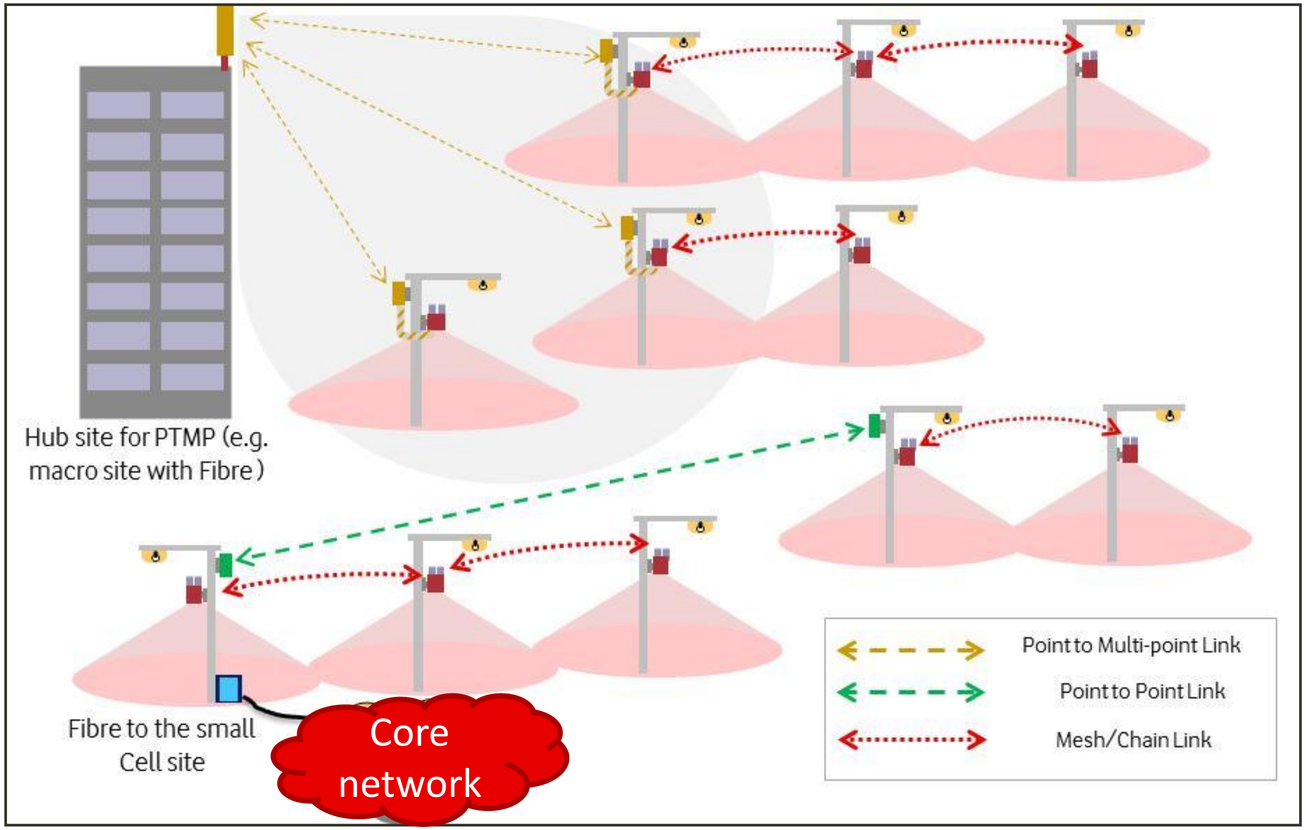
seamless mobility

user transparency

self organization

backhaul: major challenge for small cells

smaller cells



small cell backhaul will require a mix of fibre & wireless

future residential traffic demands require fibre

smaller cells

residential fibre demand

long term bandwidth requirements of around **100-300 Mbps** downlink and **30-100 Mbps** uplink **per household** driven by concurrency of services, cloud services, and video

higher level symmetry driven by new real-time video applications telepresence, teleworking, remote monitoring/care, etc.

- Today in Europe cable (fibre/coax) represents the majority of new next generation roll-outs
- why? fibre to the home is very expensive for one entity to deploy and ecosystem is broken
  - not attractive to access seekers – bitstream access not sustainable
  - does not fit with co-investment model
  - uncertain return on investment for a single operator (even incumbents)

NG-PON2: opportunity to get it right

smaller cells

1st

2nd

long reach ?
high splitting ratio ?
central office consolidation ?
open access ?
co-existence ?
capable of ≥1/1Gbps per customer ?

NG-PON2

technology generation ~every 5 years.
next opportunity not before 2020!

XG-PON1

increased speed (10/2.5Gbps)
co-existence with legacy
same principles as GPON

GPON

asymmetric speed 2.5/1.25Gbps
bandwidth shared by ≤ 64 users

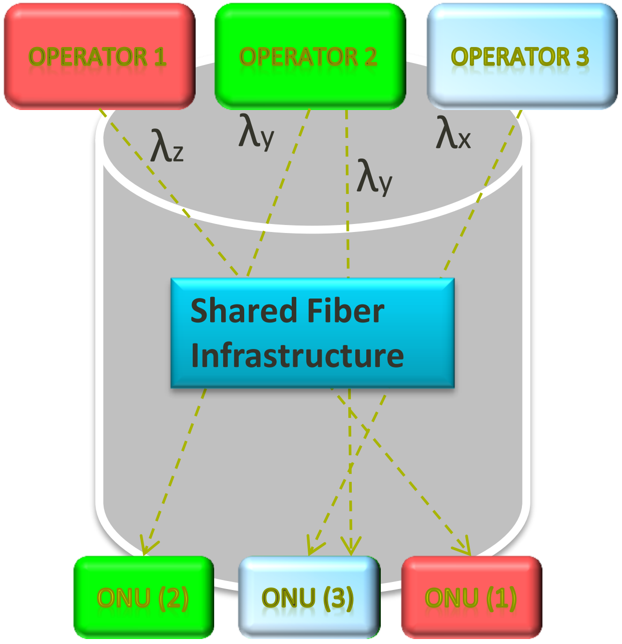
2006 2010 2015

NG-PON2 must be an open and future-proof technology

why wavelength unbundling?

smaller cells

- stimulate investment and innovation
  - access seekers can access wavelengths on fibre
  - replication of Local Loop Unbundling (LLU) economics
  - avoid uneconomical fibre to the Home (FTTH) infrastructure replication
  - stimulates competition and innovation (not constrained as in bit stream model)
  - enables sharing of fibre access for small cell backhaul



conclusion

- global fragmentation and lack of sufficient spectrum can potentially slow down mobile internet with huge impact on the economy
- mobile traffic growth will be accommodated through exploiting more spectrum (licensed and unlicensed), smaller cells, and multiple radio technologies (hierarchical & heterogeneous)
- need continued R&D in techniques for multisite signal processing
- multiband radios with good RF performance are crucial today and even more important and challenging moving forward
- WDM technology is key to allow wavelength unbundling. make FTTH a reality, and also accelerate small cell roll out.