



Beyond LTE-A: MediaTek's View on Rel-12



3GPP TSG RAN Workshop on REL-12 and Onwards,
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Outline

- History, Forecast, and Challenges
- Technological Elements for LTE Evolution
 - Spectrum-agile LTE deployment
 - TDD small cell and WiFi
 - Small-cell improvement
 - Advanced interference handling in HetNet
 - Role of advanced receiver
 - MIMO and CoMP
 - eDDA
 - MDT
 - Low cost M2M
- Conclusions

Mobile Data Traffic Growth: History and Forecast

➤ Historical forecast versus actual

- Global mobile data growth today is similar to global internet growth in the late 1990s
 - Regional growth pattern can deviate a lot from global average
- Forecast started in 2008/2009 with a wide range of 5-yr CAGR (69%~131%)
 - Year #1-3 (2008→2009→2010→2011) actual CAGR: ~2.5x.

➤ Exponential growth at early stage, but with decreasing growth rate at later stage

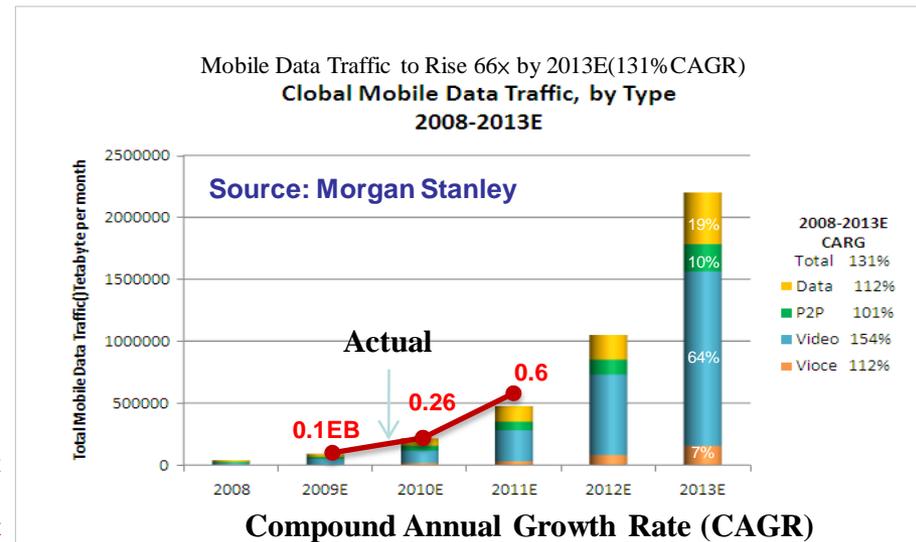
- Cisco's CAGR forecast revised down year-over-year: 108% ('10) → 92% ('11) → 78% ('12)
- Early stage with increase of both subscribers and per-subscriber growth
- Later stage with saturated user penetration and also lower per-user growth

Global Internet Traffic Growth (Fixed)	
1997	178%
1998	124%
1999	128%
2000	195%
2001	133%
2002	103%

Global Mobile Data Traffic Growth	
2009	140% 0.1EB
2010	159% 0.26EB
2011	133% 0.6EB
2012 (estimate)	110%
2013 (estimate)	90%
2014 (estimate)	78%

Yr 1-3: ~2.5x
Yr 4: ~2x
Yr 5-6: ~1.8x

Source: Cisco VIN Mobile, 2012



What is a Good Five-year Target?

- **Predicting future can be risky**
 - 10-yr forecast is doomed to be incorrect
 - Doubling for 10 years $\rightarrow 2^{10}=1024x$!!
- **UMTS Forum report 44 (Jan 2011) more conservative than Cisco VNI (Feb 2012)**
 - See below
- **At least prepare for 12~18x in the next 5 years (2011 ~ 2016)**
 - More than doubling in the first years

Global monthly traffic (EB)	2010 (act.)	2011 (act.)	2015 (est.)	2016 (est.)	2020 (est.)	2025 (est.)	CAGR
Cisco VNI	0.26	0.6 (1x)	6.9 (12x)	10.8 (18x)			78% (2011-2016)
UMTS Forum	0.32 (1x)		3.78 (12x)		10.6 (33x)	29.3 (91x)	42% (2010-2020)

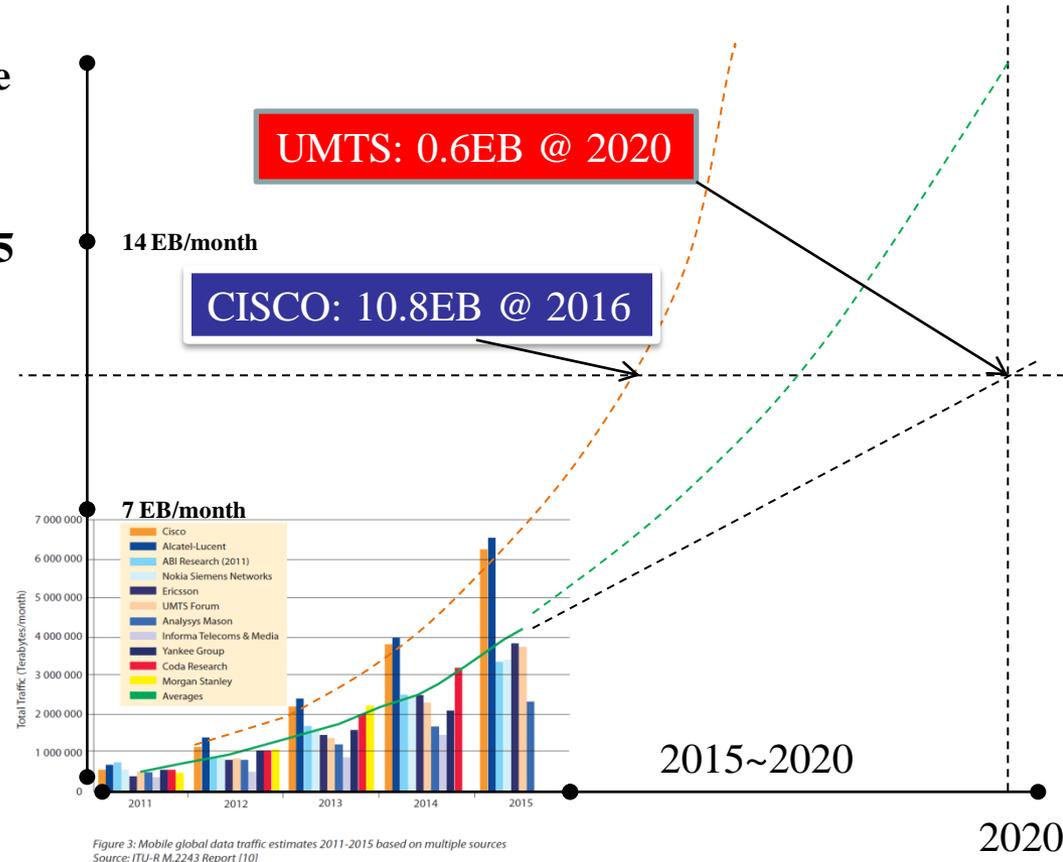
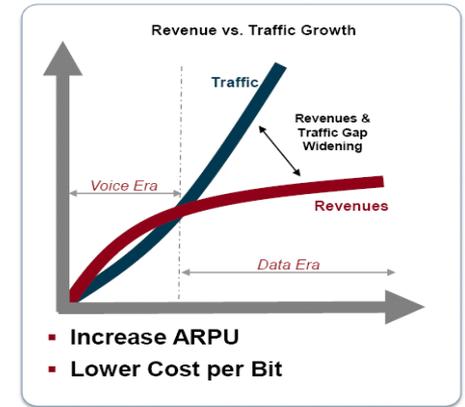


Figure 3: Mobile global data traffic estimates 2011-2015 based on multiple sources
Source: ITU-R M.2243 Report [10]

Challenges

- **Slow ARPU growth compared to traffic growth**
- **Spectrum**
 - Not enough, at least from an individual (i.e., “non-collective”) perspective
 - Fragmented for establishing economy of scale and supporting roaming
 - Operators’ utopia: UE supports all my spectrum holdings, and any CA combination !
 - Agile spectrum usage between legacy needs and LTE migration and among cells
- **Quality/availability expectation**
 - Availability at an “acceptable” rate commensurate with the user expectation for the service of interest
 - Operator network quality is more weighted by the 20% worse cases (cell-edge differentiator)
- **New Services and traffic characteristics**
 - Smart-phone’s “heavy” interactive background traffic is dragging networks
 - Small packets “light” sparse background traffic (e.g., MTC) needs high signaling efficiency
 - Mobile video is already >50% of total data traffic. Predicated to grow to >70%
 - Embedded LTE device can emerge in large numbers
 - Mobile video calling may be a LTE killer app?
- **Backhaul and network (self-)configuration**

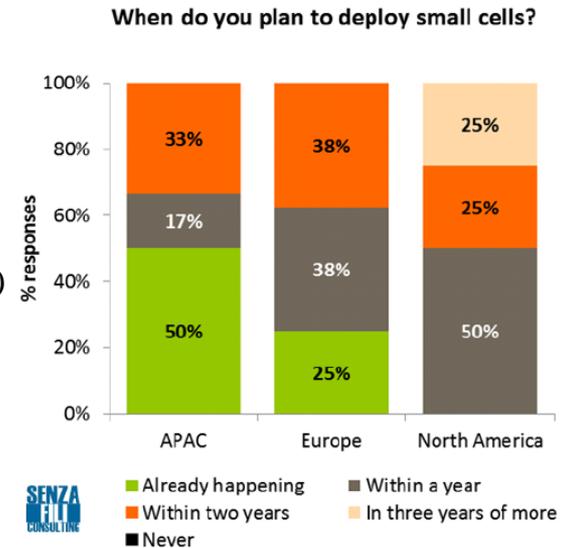


What Operators Can Do?

- **More spectrum for LTE**
 - Short-term: Acquire new licensed LTE spectrum
 - Obvious solution to bring linear growth to capacity
 - More cost-effective in the short term than perhaps adding sites
 - Mid-term: Migrate 2G/3G in existing bands to the more efficient LTE network
 - Long-term: Network sharing, Cognitive spectrum usage
- **But at some point, more cells are required to meet the traffic needs**
 - Small-cell also results from higher frequency spectrum deployment

- **An example path to get 12-18x capacity**

- 2x spectrum
- 2~3x spectrum efficiency
 - Feasible with much improved SINRs in small-cell deployment
 - LTE Rel-8 can achieve 4bps (InH) compared to 1.45bps (UMa) (TR36.814, uncorrelated antennas)
- **3~4x from cell splitting (“Small-cell”)**
 - Similar gain observed already with HetNet (1 macro + 4 pico)



UE's Role and Challenges

- **Inevitable to deal with increasing network complexity**
 - Dense eNB deployment, different eNB types, and operating bands
 - Multiple Radio Access Technologies (RATs, including WiFi)
 - Aggregation of any subset of band combinations or band+RAT combinations → A large number of potential deployment and migration scenarios !
- **UE's capability to sense and mitigate interference in a dense network will become critical**
- **Standards development must be very cognizant about spectrum- and feature-induced fragmentation and resulting lost of economy of scale**
 - Think about the success of WiFi (2.4GHz and 5GHz) and GSM (quad-band) !
 - Balance the desire for network flexibility/configurability with UE complexity
 - Benefit of configurability and use case should be proven before UE support
 - Consider user experience (e.g., power consumption) when sharing the burden of traffic explosion with the network
 - Avoid defining multiple solutions to similar issues under slightly different scenarios
 - e.g. interference issue on control: ePDCCH, cross-carrier scheduling, CoMP, eICIC receiver

Spectrum-Agile LTE Deployment Support

- **For R12, efficient use of spectrum (scattered) is still the key objective in the HetNet era, complemented by other desirable system properties including:**
 - Agile use of the spectrum among multi-tier/layer eNBs:
 - New or re-farmed
 - Spectrum resources dynamically available from a pre-R12 LTE system (or non-LTE)
 - Pair or unpaired
 - TDD operators can have augmenting FDD spectrum
 - FDD operators can have augmenting TDD spectrum
 - Licensed or shared
 - Energy efficient eNBs
 - Be able to turn on-off for both energy saving and interference mitigation
- **Spectrum strategies in HetNet**
 - All eNBs are capable of using all the spectrum holding
 - Spectrum overlay (e.g., macro-layer for coverage and pico/femto-layer for capacity)
 - Hybrid of above
- **Towards a self-configurable spectrum-cognitive network**
 - Adaptive spectrum usage in observance of interference and traffic pattern

Spectrum-Agile LTE: Building Blocks for R12

- **R10/11 carrier aggregation (CA): A step-stone for spectrum support**
 - CA-capable UE allows network to use the scattered spectrum more efficiently
 - UE complexity and power consumption are the price paid
- **“CRS-free” or “CRS-reduced” carrier potentially makes spectrum usage more dynamic, and also does not cause interference during “off period”**
 - DMRS based demodulation (PDSCH and ePDCCH)
 - CSI-RS based link adaptation
- **New carrier type (NCT)**
 - CRS-reduced & non backwards-compatible
 - Used as “S-cell” only with mobility procedure still based on “P-cell”
 - Use case needs further discussion in R12 in the context of HetNet:
 - Precious spectrum not accessible to legacy UEs and can be used as S-cell only
 - The need of operating NCT as a stand-alone carrier, in addition to as S-cell
- **TDD inter-band CA support may also trigger the convergence of RF FE**
 - Full duplex operation in TDD inter-band CA with different DL-UL split
- **R12 could continue the ePDCCH and NCT studies, further including mobility and UE-assisted network auto-configuration**

LTE TDD Small-Cell versus WiFi

- **TDD spectrum is well suited for LTE small-cell deployment**
 - LTE and WiFi will live with each other as LTE moves to higher spectrum deployment
 - WiFi offloading is an important tool to address traffic explosion
- **Adaptive TDD (R11 study item) showed the “WiFi-like” operation can provide gain under a small per-cell UE population**
 - R12 can build upon the findings to focus on adaptation mechanism and interference management, both among small cells and between small-cell and macro TDD cells
- **LTE small-cell value proposition**
 - Licensed spectrum
 - Better QoS for enterprise quality mission critical application
 - Hotspot, large population that demand better access technology (grant based versus collision-detection based)
 - Seamless mobility among macro/pico/femto
 - Interference coordination and handling
 - Simply making LTE as cheap as WiFi might not be the right value adding
 - e.g. UL OFDMA for TX and RX commonness is not a convincing value adding than perhaps allowing better UL-MIMO and spectrum utilization

Small-Cell Improvements: System Aspects

- **Current HetNet mobility study in 3GPP**
 - Cell search & Power consumption
 - Search for off-load purpose cannot currently be optimized the same way as search for coverage, and is often not useful as UE is often not in offload coverage.
 - UE Speed
 - Small cells and small cell layers do not support highly mobile UEs well, neither connected UEs nor Idle UEs.
 - Legacy UE mobility state estimation is too unpredictable to be used with heterogeneous size cells
 - Connected mode DRX
 - Using connected mode long DRX may involve low handover performance, resulting in high signaling overhead for connection recovery.
 - It should be possible to keep UEs in connected mode long DRX, without extensive signaling for connection recovery.
 - Recovery
 - LTE connection recovery is rigid and could be optimized for less connection interruption.
- **Enhancements are useful. Work is likely to extend into Rel-12 and later.**

Advanced Interference Handling

- **While adaptive spectrum self-configuration may mitigate inter-cell interference as much as possible, co-channel interference handling is still the key for spectrum efficiency (for both macro and HetNet environments)**
 - To ensure cell splitting gain in a dense network
 - To ensure cell-edge throughput meet the 4G user expectation (“fast every where”)

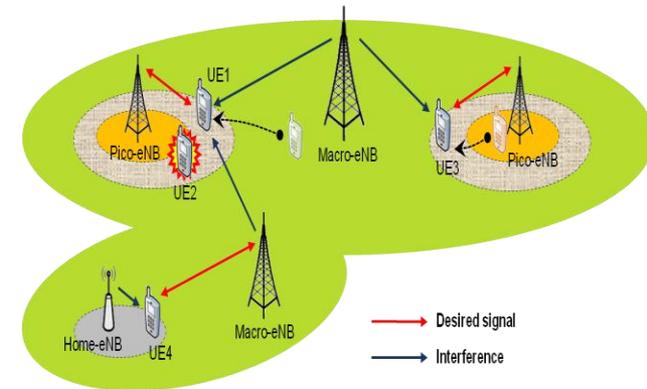
- **All three domains should be leveraged in a coherent fashion**
 - Time domain deployment strategies
 - Subframe level coordination in non-CA based eICIC
 - Frequency domain deployment strategies
 - FDM and ePDCCH
 - Space domain complementary techniques
 - CoMP
 - 3D-MIMO (including electronic antenna tilting)

MIMO and COMP (Rel-10, 11 and 12)

- **Macro-cell spectral efficiency and coverage improvement is still very important in the HetNet era.**
- **DL-MIMO enhancement**
 - Well-studied in Rel-10, 11, and again in Rel-12 (under enhanced DL-MIMO WI)
 - Target cell capacity gain with MU-MIMO optimization (X-pol antenna particularly)
 - Challenge for eNB to obtain channel knowledge to mitigate MU interference
 - **R12 should target maximal gain for MU-MIMO for both macro and small cells**
 - UE can be very effective in canceling residual MU interference
- **“3D” beamforming (i.e., elevation + azimuth)**
 - **Elevation represents a new dimension of a channel that will be first studied in R12**
 - Basis for studying antenna panels with a large number of antenna elements
- **CoMP**
 - Well-studied in Rel-10 & 11
 - Fast dynamic eNB/RRH coordination requires fiber backhaul and centralized scheduler
 - **Rel-12 could investigate X2-based CoMP with large latency and low data rate**
 - But, X2-based CoMP needs to be assessed along with other HetNet interference handling techniques

Role of Advanced Receivers

- **UE's advanced signal processing will become more important**
 - Similar trend in HSPA: type 1,2, 3, 3i receivers
- **Interference Rejection Combining (IRC)**
 - Treat interference as colored noise and use dual-Rx to mitigate
 - Expected to become the baseline receiver (MMSE-IRC) for Rel-11
 - 3GPP system level Tput gain: 5-25% for 5%-tile users, 3-7% for cell average
- **Explicit Interference Cancellation (IC)**
 - Cancel reconstructed interference signals
 - Main use case in R11: small-cell with range expansion
 - Potentially cancel PSS/SSS, PBCH, and CRS
- **IC capability should be exploited more often in R12**
 - Require both network and UE to work together
 - System design to make the interference more cancellable
 - Synchronous deployment
 - Means to facilitate robust cancellation
 - Tightened link adaptation to translate link-level gain to system level gain, especially for sporadic packet traffic



MDT and eDDA

■ MDT potential scope in R12

- LTE only, focus on enhancements to existing use cases.
- QoS verification enhancements
 - Data Loss
 - Latency measurement.
- Coverage characterization enhancements
 - DL common channels acquisition performance

■ eDDA potential scope in R12

- Ensuring high efficiency for traffic that bring demanding requirements for user-plane or control-plane.
 - Continue focus on traffic that need to have low cost and low resource consumption
 - MTC traffic, “always on” background traffic, Interactive messaging
 - Supporting large number of UEs in typical network scenarios
- Objectives
 - Low signaling overhead for signaling for Uu L1/L2/L3, NAS, Core Network
 - High Uu transmission efficiency
 - Good and controlled QoS
 - Good UE battery performance

LTE-based M2M

- **Low-cost MTC:**
 - Smart grid, home automation, eHealth, etc.
 - **R12 can further study/specify the following cost-saving techniques:**
 - Reduced BW
 - Single Rx antenna
 - No coverage reduction compared to normal LTE coverage
 - Reduced peak rate
 - Half-duplex FDD

- **Broadened M2M scope: embedded devices**
 - Need to ensure high efficiency for M2M traffic that bring demanding requirements for user-plane or control-plane
 - **Include optimization of M2M traffic handling in R12 eDDA, such as**
 - Low signaling overhead for signaling for Uu L1/L2/L3, NAS, Core Network
 - Good UE battery performance

Summary of Per Device Usage Growth, MB per Month

Device Type	2010	2011	2016
Nonsmartphone	1.9	4.3	108
E-reader	0.5	0.73	2.8
Smartphone	55	150	2576
Portable gaming console	244	317	1,056
Tablet	405	517	4223
Laptop and netbook	1,460	2,131	6,942
M2M module	35	71	266

Source: Cisco VIN Mobile, 2012

Comparison of Global Device Unit Growth and Global Mobile Data Traffic Growth

Device Type	Growth in Users, 2011-2016 CAGR	Growth in Mobile Data Traffic, 2011-2016 CAGR
Smartphone	24%	119%
Portable gaming console	56%	76%
Tablet	50%	129%
Laptop and netbook	17%	48%
M2M module	42%	86%

Source: Cisco VIN Mobile, 2012

Conclusions

- **Prepare for at least 12-18x capacity increase in 5 years**
 - Exponential traffic growth but a slow revenue growth
 - Lower cost per bit (more spectrum for LTE)
 - Embedded device and M2M to drive subscriber growth
- **Efficient use of scattered spectrum is still the key objective in the HetNet era**
- **Establish a solid footing in Rel-12 for LTE everything everywhere**
 - Spectrum-agile LTE deployment support
 - Small-cell improvement
 - Advanced interference handling & Advanced receiver
 - eDDA
 - Low-cost MTC
- **Balance the desire for network flexibility/configurability with UE complexity**
- **Avoid defining multiple features addressing similar issues**

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Thanks!

