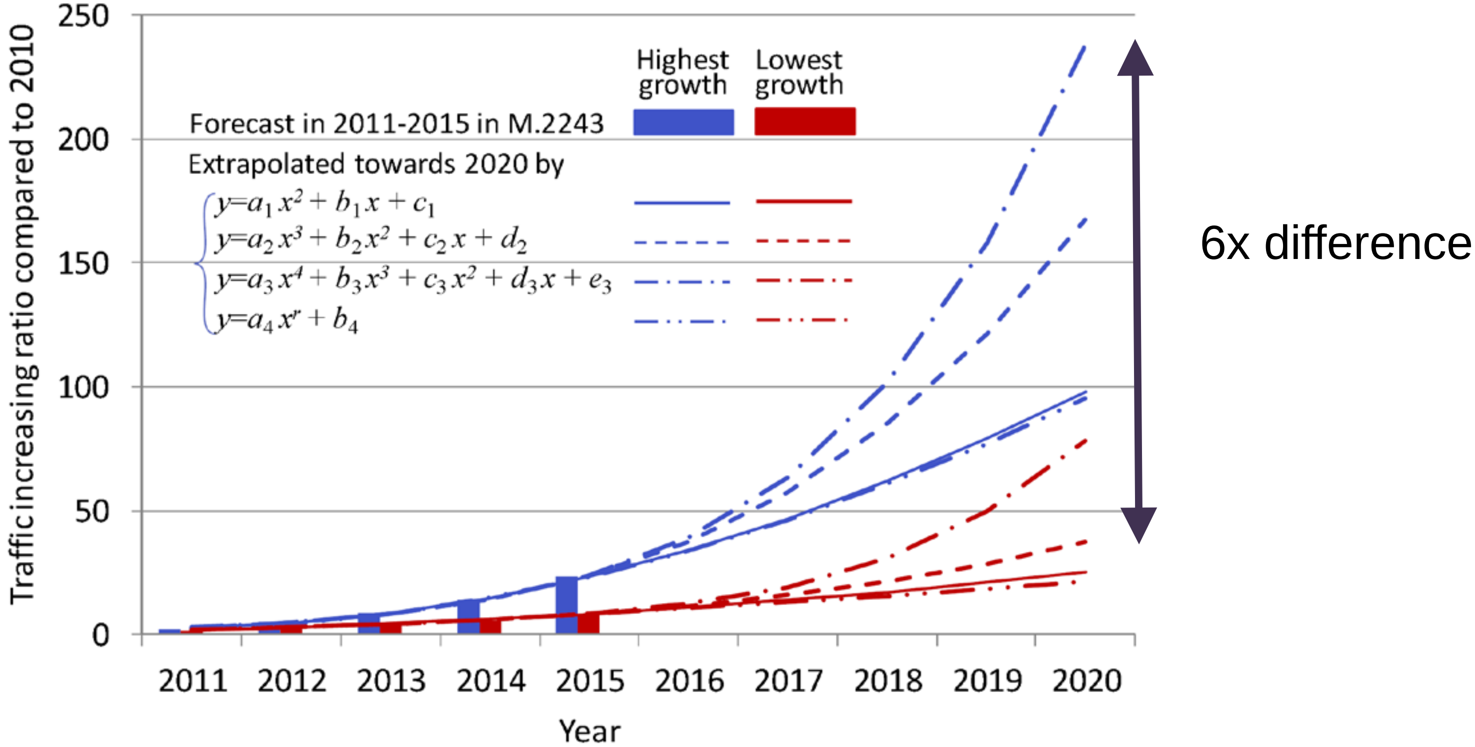
Future of Spectrum Management

“Watch the Herd?”

Trends Today

- Liberalization / technical neutrality of spectrum usage within a band
- Exaggerated or unrealistic predictions for mobile broadband spectrum use
- Blurring of the lines between services (broadcast, point-to-point, cellular, broadband)
  - Services vs delivery mechanisms
- Geographic spectrum sharing is becoming more mainstream

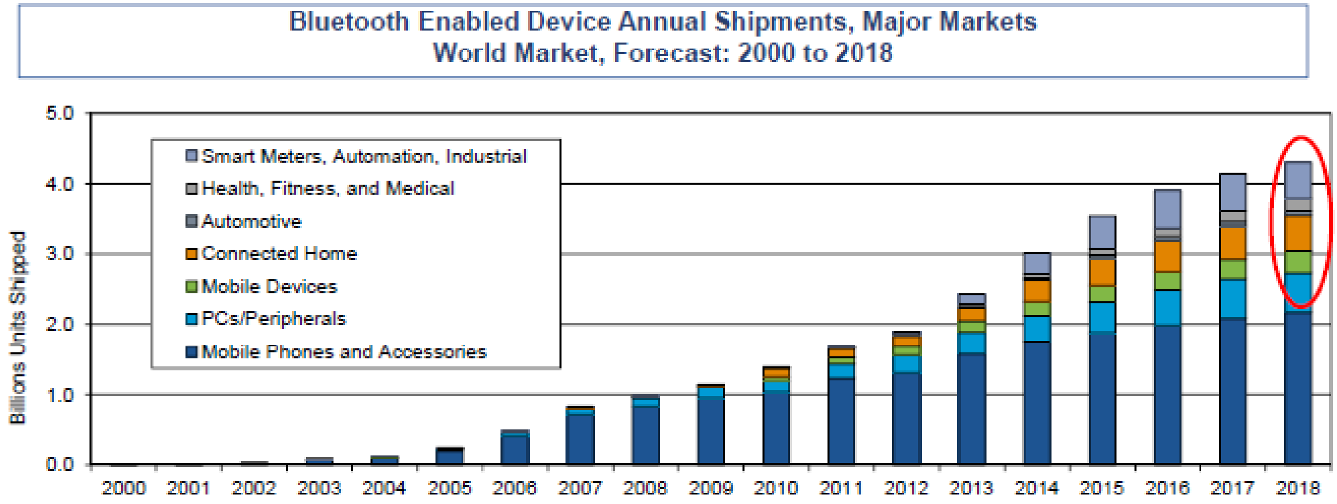
High variability within a single estimate that grows without any bound



- **Report ITU-R M.2290-0 (12/2013) Future spectrum requirements estimate for terrestrial IMT**
  - 24% Annual Growth Rate to 47% Annual Growth Rate to 63% Annual Growth Rate

More devices does not always require more spectrum

- **2-3 Billion Bluetooth shipments in 2014 and estimates are for 4-10 Billion units worldwide (per year) by 2018 without any outlook for new spectrum**
- **Bluetooth devices are considered to the be the first generation of Internet of Things (IoT) devices**
- **Number of devices, amount of data used per device, proximity to infrastructure (i.e. buildings), availability of power all impact the need for spectrum**



Jonathan Kaye, Laird Technologies (2014); ABI Research, Inc (2013); Bluetooth.Org (2011-2014)

Mobile broadband demands are met by multiple mechanisms (efficiency, number of base stations, and spectrum)

- **Traffic is met combining the use of licensed spectrum (cellular data plan) and WiFi offloading (using home or work local network)**
  - Consumers get faster data rates and thus can download large data (movies, pictures, etc) more quickly for a better user experience
  - Users with data limits need to lower use of cellular data or risk surcharges
  - Offloading estimates vary between 50-90% of the total data
- **Frequency reuse (also known as cell splitting) directly increases the network capacity for each base station**
  - A base station that can provide 100 million bits per second (Mbps), then 10 base stations can provide a network capacity of 1,000 Mbps (10 times)
  - Typical national deployment is 40,000 base stations and femtocells could provide millions of base stations

Additional spectrum will not be a significant contributor to meet any significant increase in demand

- **Assume that traffic increases by greater than 10 times (a lower estimate shown earlier); what can be used to provide those gains**
  - 100 MHz of additional spectrum represents only a **20% growth** in the currently assigned 500+ MHz allotment
  - More Base Stations (Additional 1 M femto cells) = **25x growth**
  - Higher efficiency due to smaller cells = **2-3x growth**
  - Additional WiFi spectrum and Home High Speed Internet (change from 80% to 95% offloading) = **4x growth**
- **Positive effects of new spectrum**
  - New spectrum can provide resources for increasing competition for a new entrant

Additional spectrum will not be a significant contributor to meet any significant increase in demand

Contributor	Improvement	Current	Gain
More Base Stations	1,000,000 femtocells	40,000 base stations	25.0x
WiFi Offloading	95% offload	80% offload	4.0x (1-.8)/(1-.95)
Spectral Efficiency	2-3 bps/Hz	1 bps/Hz	2.5x
Additional Spectrum	600 MHz (addition 100 MHz)	500 MHz	1.2x

Example USA

Many futures are possible, however most are still downlink dominated due to consumer applications

- **Growth in Demand will most likely be driven be video and social networking applications**

Application	Up/Download Ratio	Comment
Video Sharing	1: Many	Basis of Sharing is to allow many to view uploads
TV Dissemination	0: Many	Broadcast of Video Streams
Video on Demand	0: Many	Unicast of Video Streams from Server
Crowd Sourcing	Many: 1 or few	
Social Networking	1: Many	Basis premise of Social Networking
Internet of Things	Many: Many Or Many: Few: Many	Battery operated devices: will have low data rates to optimize longevity “Plug-In” operated devices: will mostly have access to wireline internet access

Delivery Mechanisms

- **One-Way: Broadcast**
  - Challenge: Quality of Service …
- **Two-Way Unicast**
  - Challenge: Scalability …
- **Two-Way Multicast**
  - Challenge: Routing
- **Two-Way Hybrid Unicast (separate PHY up/downlink)**
  - Challenge: non-classic
- **Mixed PHY**

Tipping Point?

- **Technology enables access to many bands**
  - SDR and CR technologies are becoming mainstream
  - A new brand of "Ham" may emerge
- **Breadth of devices is increasing, not decreasing**
  - Hybridization of standards and hobbyist technologies
- **Multiplicity of networks to access information**
  - Infrastructure is becoming less expensive and proliferating
- **Sophistication of the "control plane" is increasing**
  - Access, dissemination, prioritization, security

Tipping Point?

- **2000-2020 Spectrum Access**
  - Resource plentiful, mechanism poor
  - Technology to open up more intensive use
  - Dynamic Access, Geographic/Time-based Sharing
  - Tradeoff between absolute interference avoidance and interference mitigation
- **2020-2040 Information Access**
  - Unicast is not the "one size fits all"
  - Technology to provide diversity of delivery mechanisms
  - Store and Forward, Distributed Servers
  - Tradeoff between common and unique access

Impact to Spectrum Management

- **Interference for many policy makers is a objective term that quantifies the impact to the service, not the link … how is this quantified**
  - Single-band, multi-band, single-network, multi-network, high-QoS, low-Qos
- **Reactive management of the resource is now possible, if the mechanisms (measurement/ reporting) are enabled**
  - How do we enable this potential (especially with US FCC reducing its enforcement role

One-Size does not fit All!

Corner Cases

Broadcast

Cellular