



# The Path to 4G: LTE and LTE-Advanced



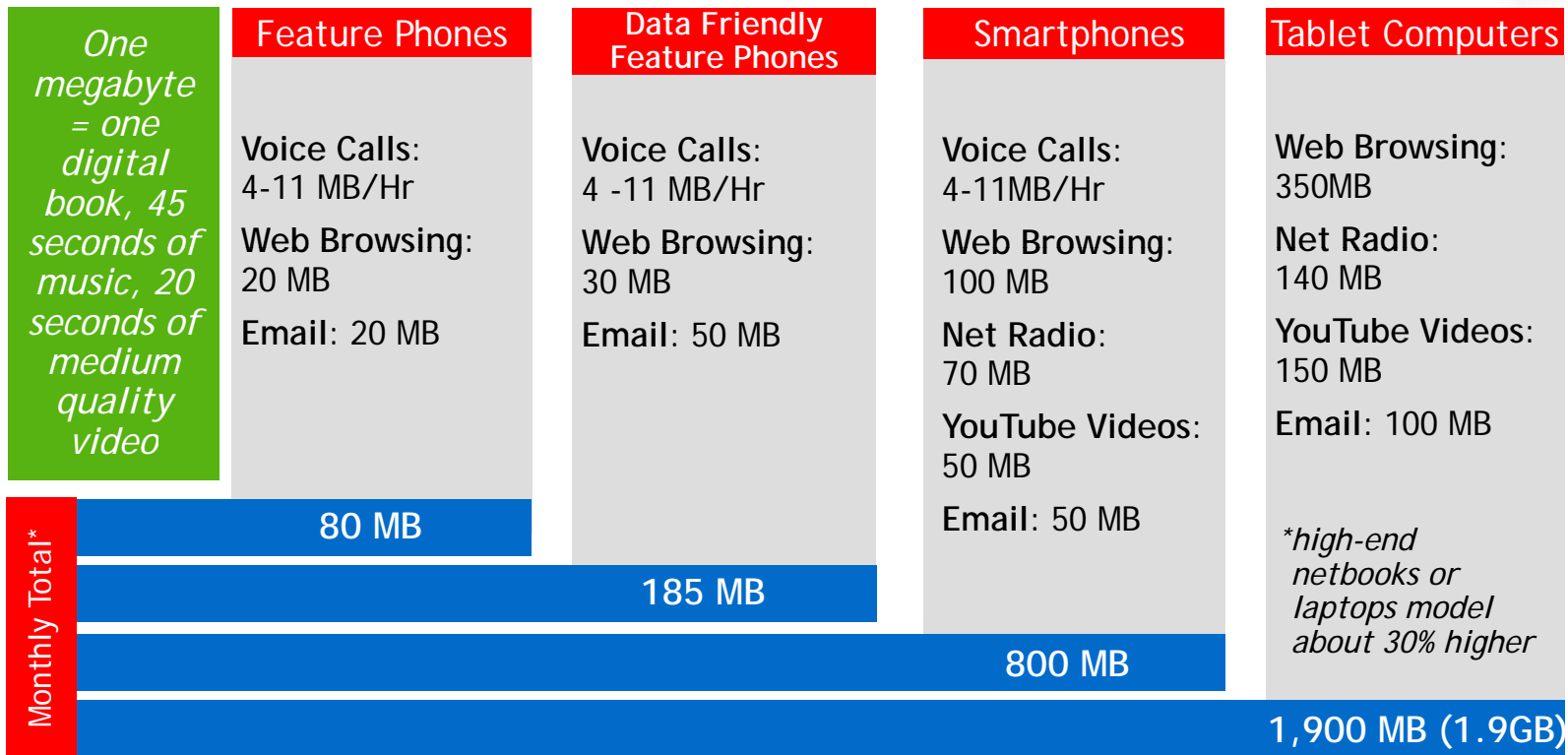
**James Seymour**  
**Senior Director**  
**Alcatel-Lucent**



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# Applications & Devices Driving Bandwidth



\* Estimated

Source: BusinessWeek (February 2010), Data: Internal Alcatel-Lucent Research



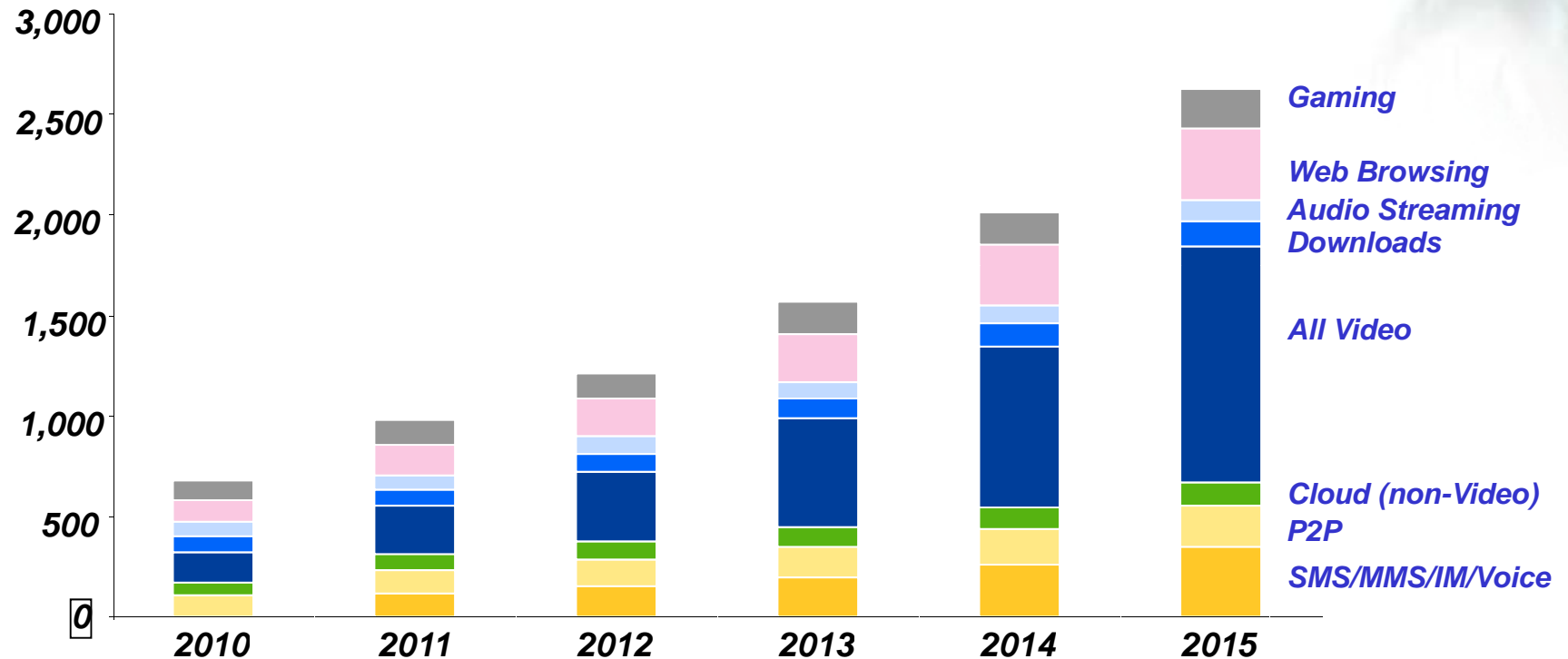
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# Smartphone User Profile for 4G



MBps/month/user



*High Growth in Web, Streaming, Interactive Video Apps  
Data Usage per LTE user projected to grow from 700MB to 2.5GB*

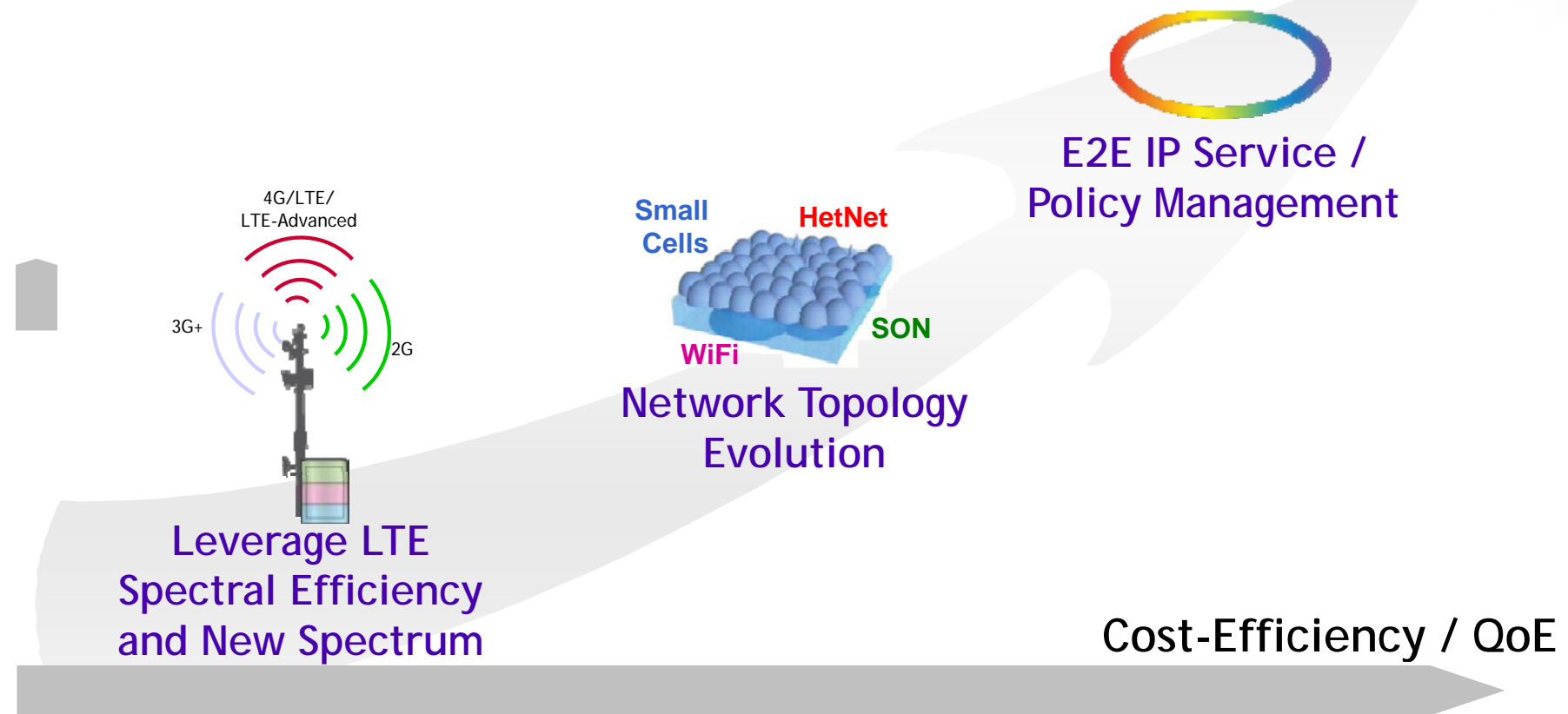


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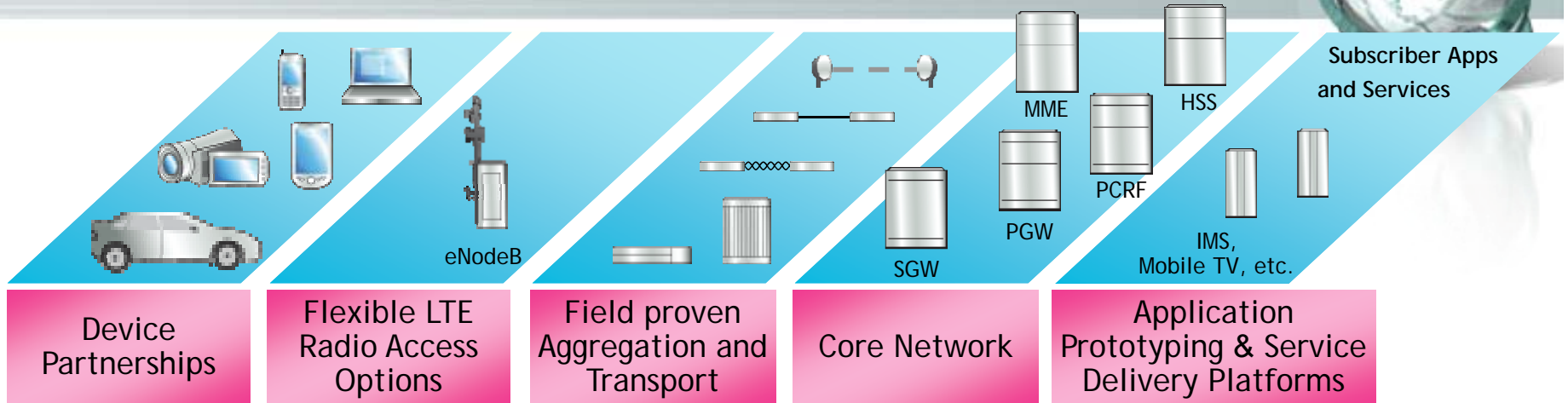


# Meeting the Fast Growing Wireless Data Capacity and User Experience Demands

## Broadband Capacity



# Achieving the End-to-End Solution



**Device Partnerships**

**Flexible LTE Radio Access Options**

**Field proven Aggregation and Transport**

**Core Network**

**Application Prototyping & Service Delivery Platforms**

*Alcatel-Lucent is paving the way to new wireless business models.*



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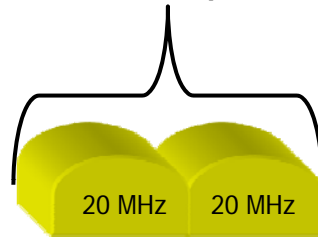


# Carrier Aggregation (CA) for LTE-Advanced



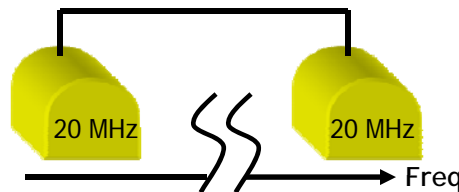
Carrier Aggregation combines multiple LTE carriers

Intra-band example: 40 MHz



Carrier Aggregation combinations defined as non-release specific.

Inter-band example: 40 MHz

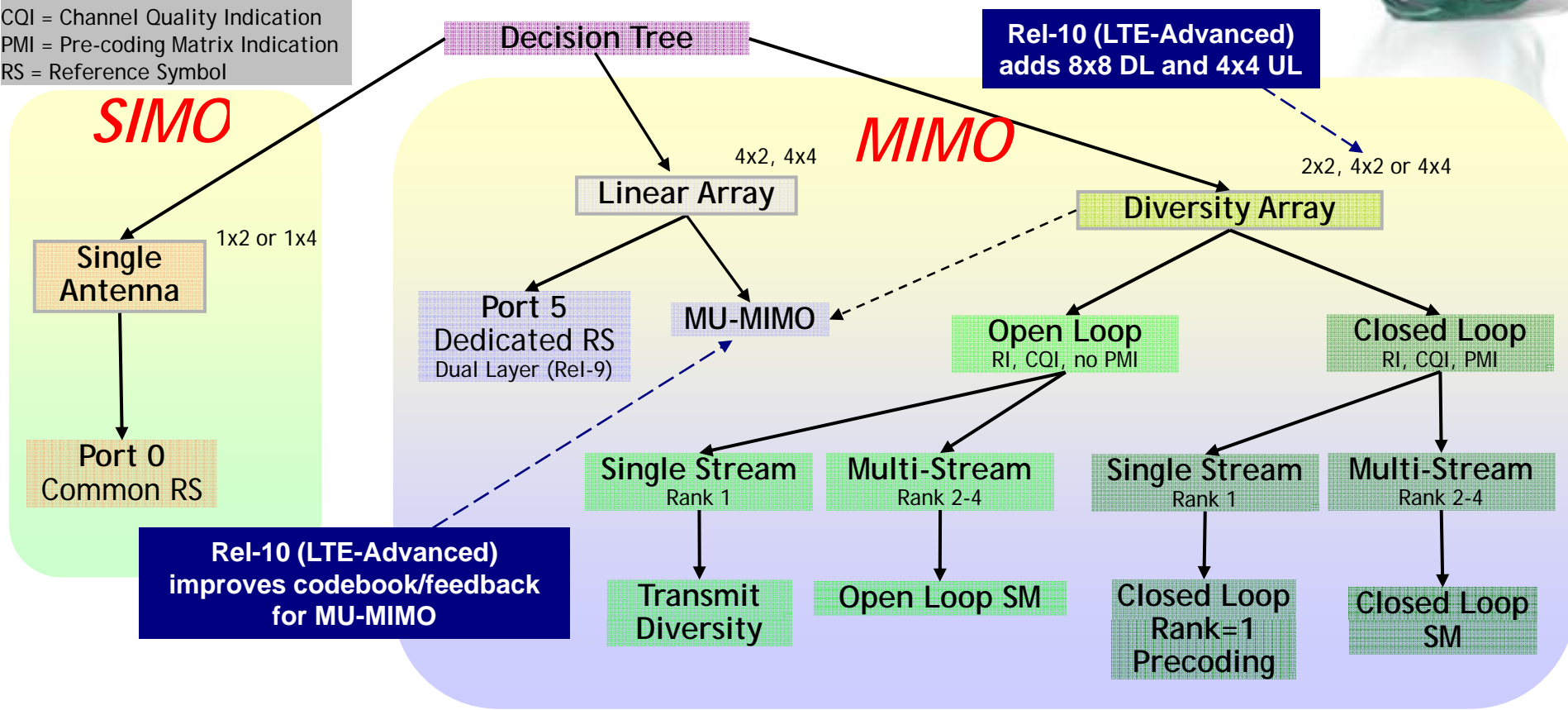


*CA Critical for meeting ITU IMT-Advanced Peak Rate Requirement (1 Gbps)*

# MIMO Enhancements for LTE-Advanced



SM = Spatial Multiplexing  
 RI = Rank Indication  
 CQI = Channel Quality Indication  
 PMI = Pre-coding Matrix Indication  
 RS = Reference Symbol



*LTE-Advanced builds off the wide range of Rel-8/Rel-9 MIMO capabilities to improve peak rates and spectral efficiency*



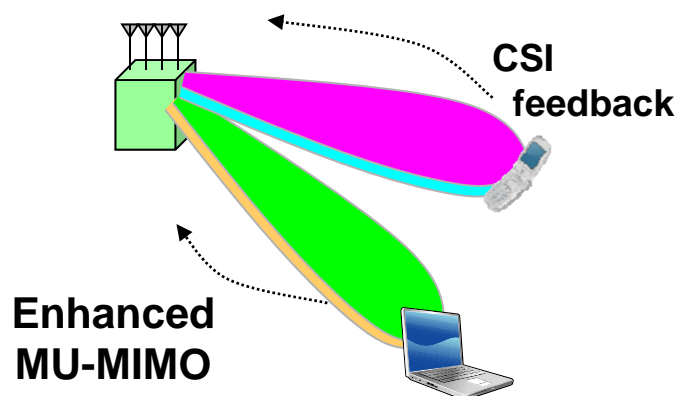
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# MU-MIMO Enhancement for LTE-Advanced



- MU-MIMO enhancements provide **up to 50% spectral efficiency gain**
- Dynamic switching between SU- and MU-MIMO supported
- Up to 2 layers per UE in MU-MIMO
- Enhanced CSI feedback structure and codebook design



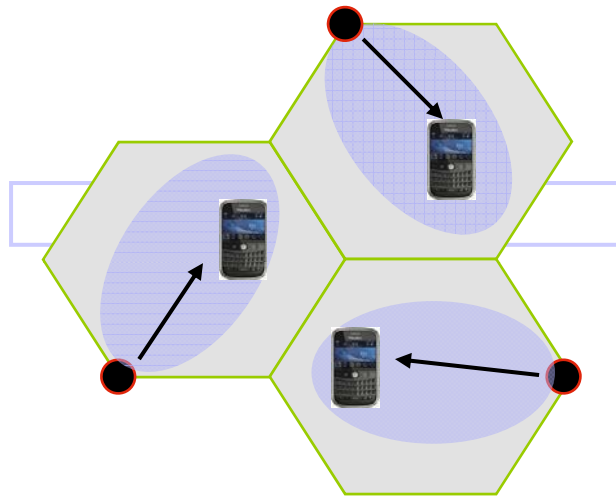
*MU-MIMO Enhancements critical for meeting IMT-Advanced DL spectral efficiency requirements*



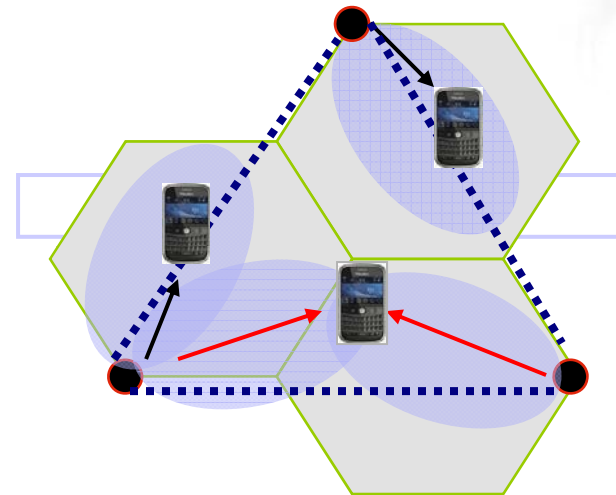
# Co-ordinated Multi-Point (CoMP) Multiple Approaches



## Interference Avoidance



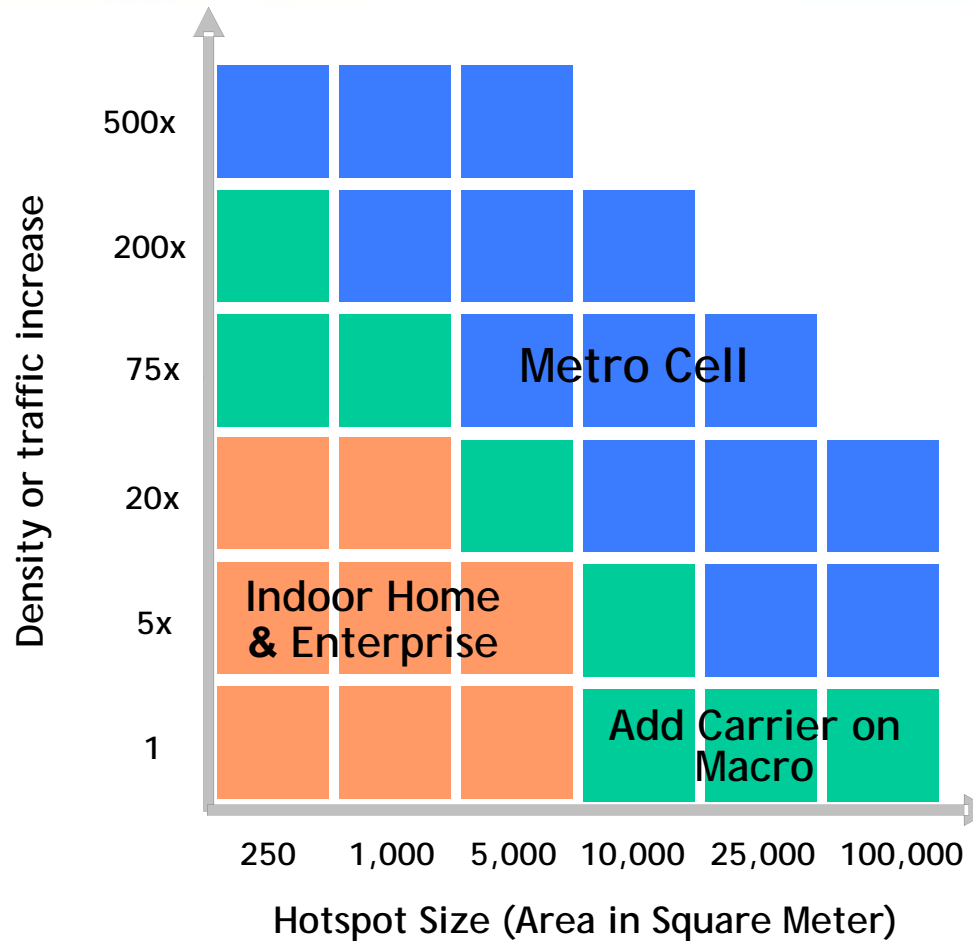
## Network MIMO



Potential 2x spectral efficiency gain 😊, but complex ☹️

*Advanced forms of CoMP only provide ~2X spectral efficiency increase  
still need more cells to meet faster growing wireless data capacity demands* →

# Where Small Cells Provide Gains



Source: Bell Labs Modeling analysis

**Home, Enterprise and Metro Cells compliment the Macro Network**



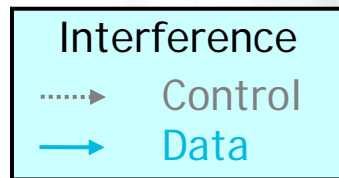
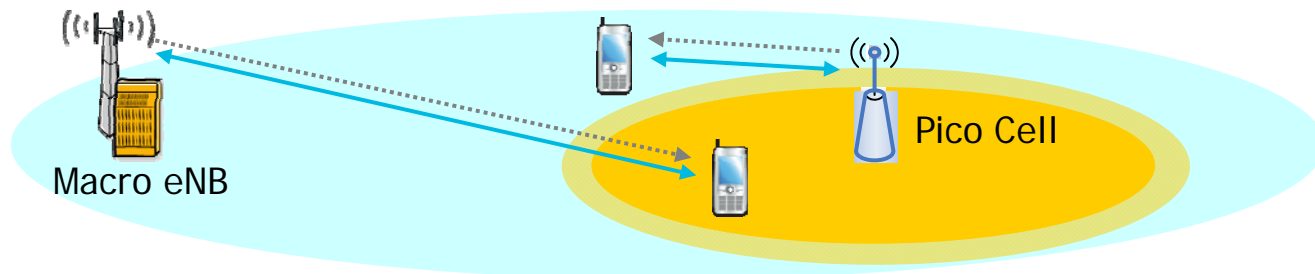
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# Interference Management with Small Cells

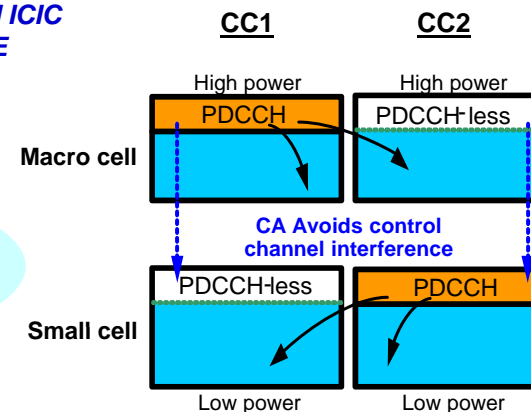
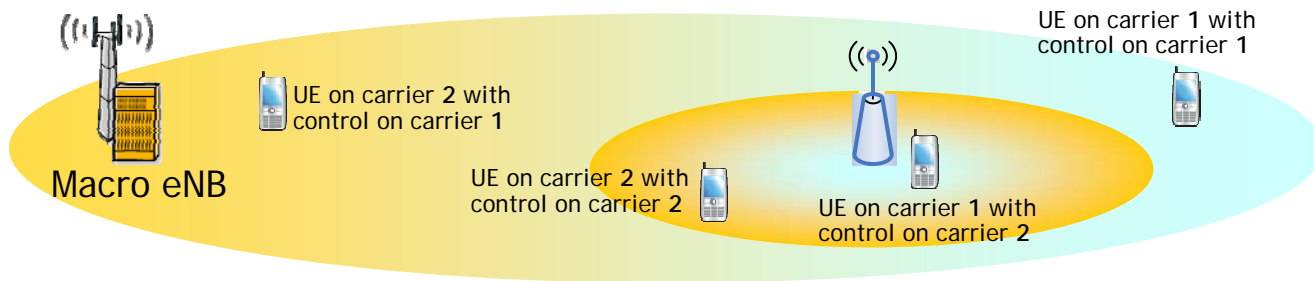


Frequency Selective Scheduling (FSS), Power Control (PC) and Inter-Cell Interference Coordination (ICIC) enables same carrier HetNet deployments for LTE



*LTE Rel-8 capabilities such can manage LTE HetNet interference.*

LTE-Advanced features such as Carrier Aggregation (CA) and Enhanced ICIC (eICIC) will further improve same carrier HetNet performance for LTE



*LTE-Advanced techniques further help to manage control channel Interference.*



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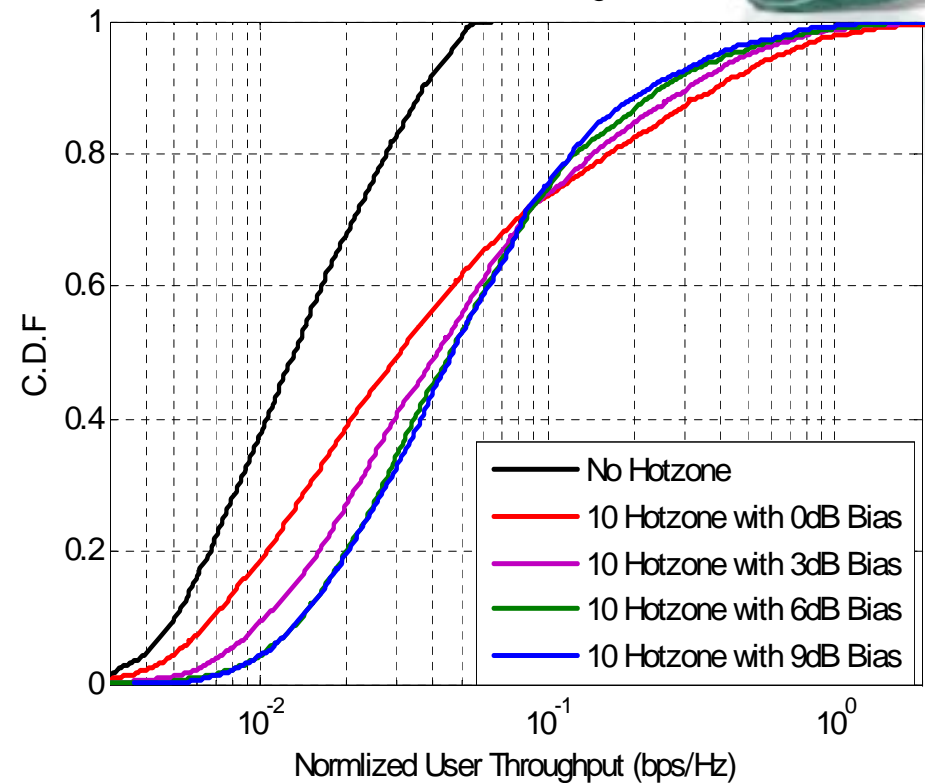
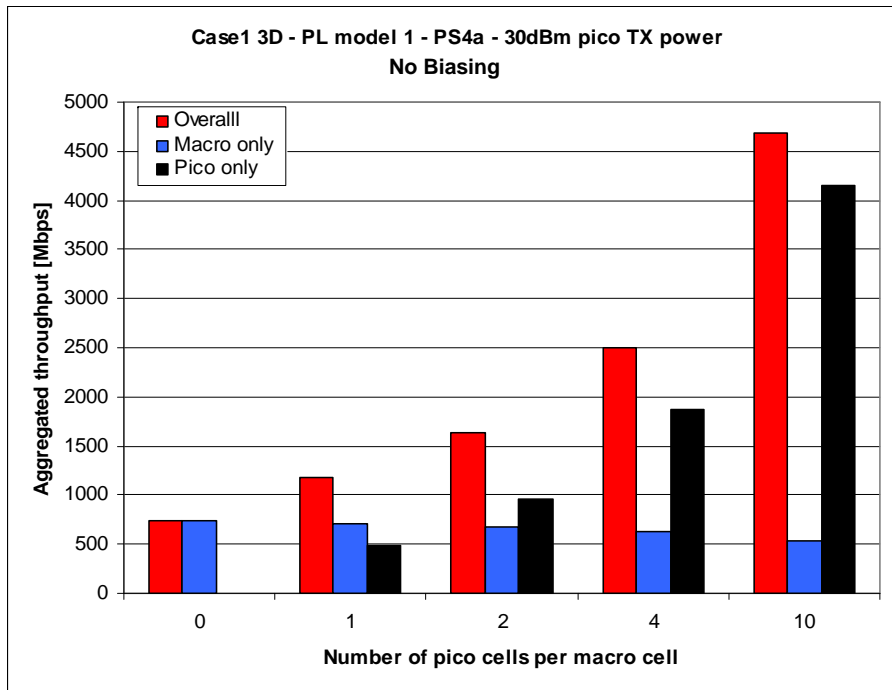


# LTE Small Cells/HetNets Performance



Source: Bell Labs Research

3GPP Case I with Configuration 4a



**Key Assumptions: Macro:** Outdoor RRH based on 3GPP Case1 (ISD = 500m, 2 GHz, 46 dBm),

**Small Cell:** 30 dBm, 4a dropping criteria → 60 UEs and constant number of small cells per macro; 2 UEs in 40m radius around each small cell; small cells and remaining UEs uniformly distributed,

**LTE Small Cell/HetNets provide significant capacity improvement critical for addressing the fast growing wireless data demands**



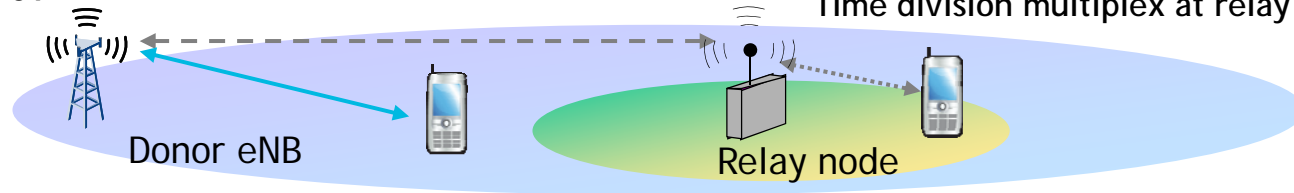
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# Relays

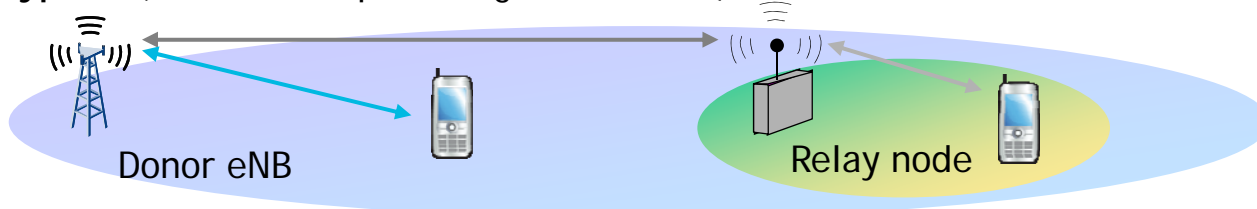


Type I (in band)



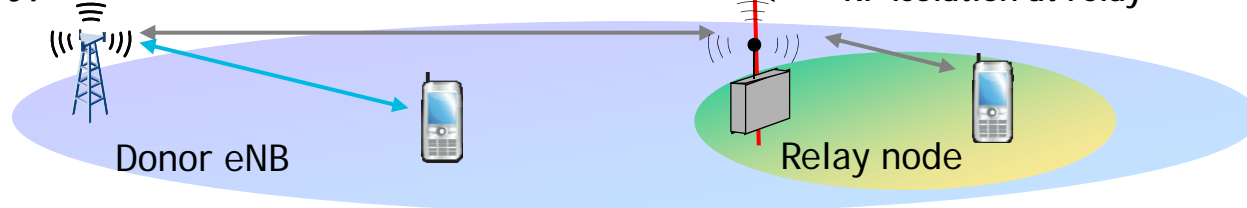
- - -> C1 time 1
- .....> C1 time 2
- > C1 or C2

Type Ia (out-of-band providing RF isolation)



- - -> C1
- - -> C2
- > C1, C2 or C3

Type Ib (in band, RF isolation)



- - -> C1
- > C1 or C2

*Relays can provide backhaul solution where dedicated backhaul is challenging*

# Self Optimizing Network (SON)

## Innovations to continue through LTE-Advanced



### Plug & play femto

### Automated neighbor cell relation

### Inter-Cell Interference Cancellation based on inter-cell negotiation

- Reduces Hand Over failure
- Improves throughput/QoE
- Performance increase in call set up

**Comprehensive** SON solution, powered by our 3G experience and Bell Labs Research



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# Summary



- **Fast growing wireless data capacity demands due to smartphones and high growth in web, streaming and interactive video apps**
- **LTE & LTE-Advanced coupled with small cells & relays will address these fast growing wireless data capacity demands**
- **Carrier Aggregation and MU-MIMO enhancements are the key LTE-Advanced features for meeting IMT-Advanced requirements**
  - CoMP has potential to provide significant further spectral efficiency gain with added complexity
  - Relays and continued SON evolution to support E2E and HetNet optimizations are additional LTE-Advanced features
- **Alcatel-Lucent is delivering market leading end-to-end LTE solution with smooth evolution to LTE-Advanced, paving the way to new business models**