The challenge of next decade mobile network and potential solutions

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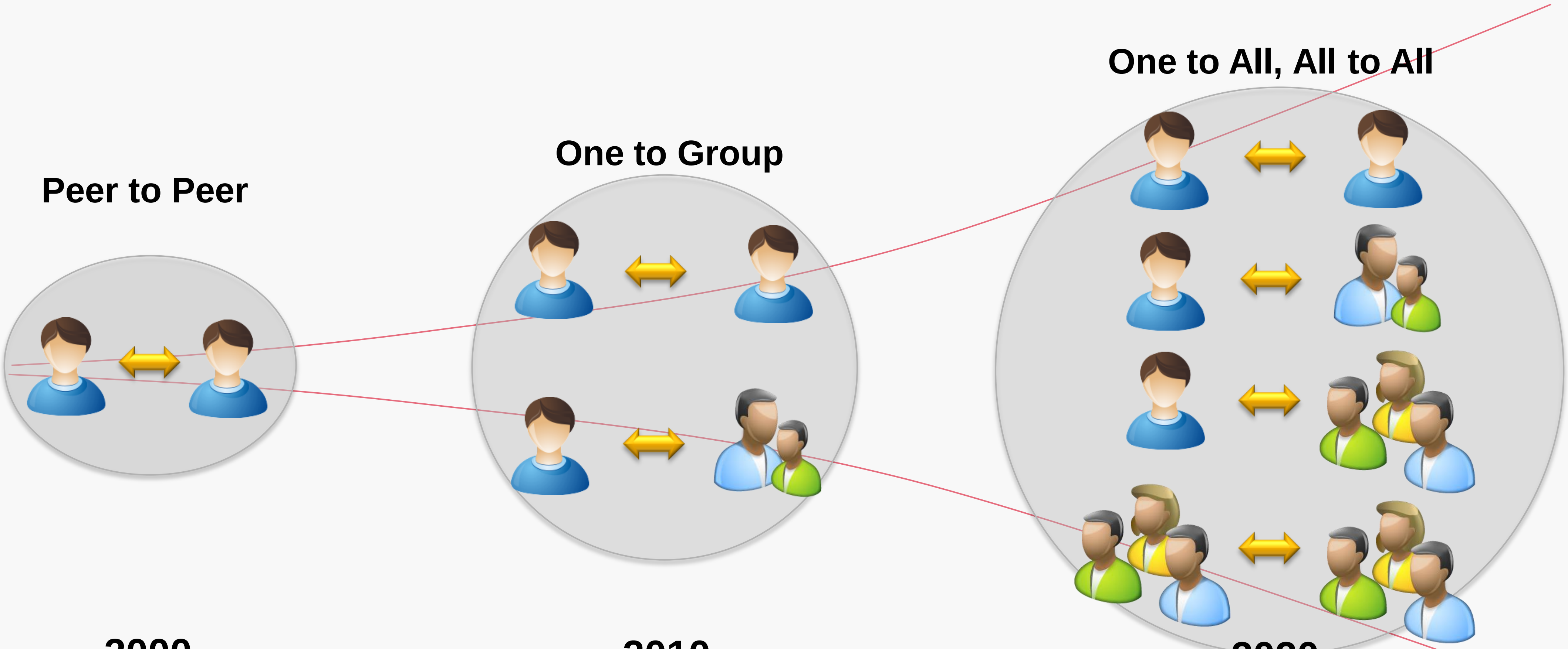
Content

- Mobile network traffic forecast
- Challenge
- Potential Solution

Beyond Voice: Changing Communications



2000
~ 0.7 Billion users
126 Billion minutes

2010
~ 5.4 Billion users
1620 Billion minutes
~ 5 Billion connections

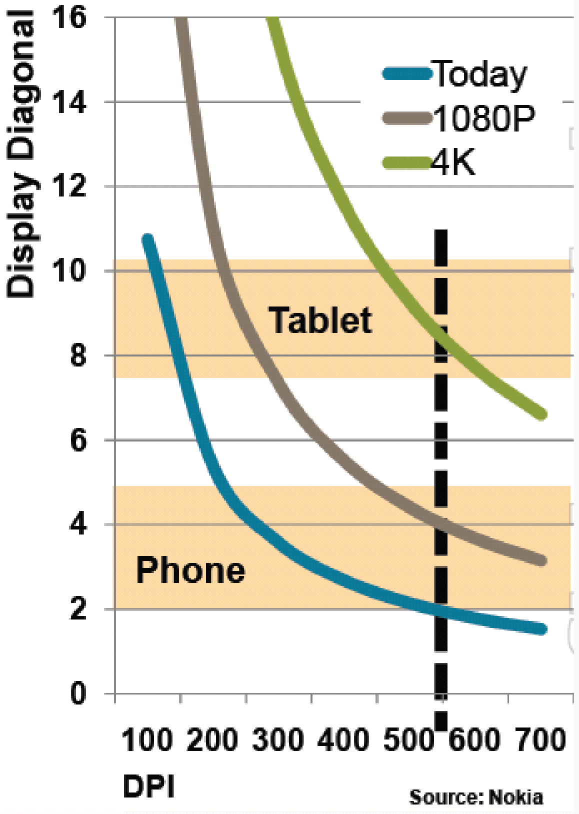
2020
~ 7.5 Billion users
3000 Billion minutes
~ 60 Billion connections

Traffic forecast on device

Eyes

- Limit to native resolution
  - 1080P @ 550DPI phone
  - 4K @ 550DPI tablet
- Display Power becomes content dependent
- Video complexity increase from 720P H.264 to 4K H.265

x16 to 64 **Display and Video**



Beyond Phone: Changing Behaviors

Personal

2000

0.02x traffic

语音+SMS

Expanded

2010

1x traffic

Internet

Infinite

2020

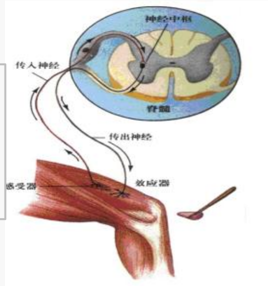
~ 500-1000x traffic

容量=小区数*RF带宽*频谱效率

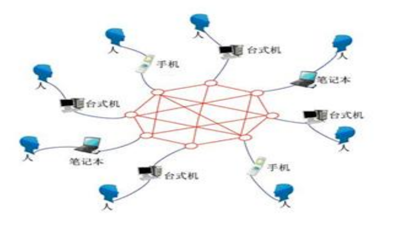
业务容量的根本问题在于频谱资源受限

网络体验感官化，要求网络响应时间无限逼近人的反应时间

Response time = sensing+ transmission + Processing + Muscle Movement



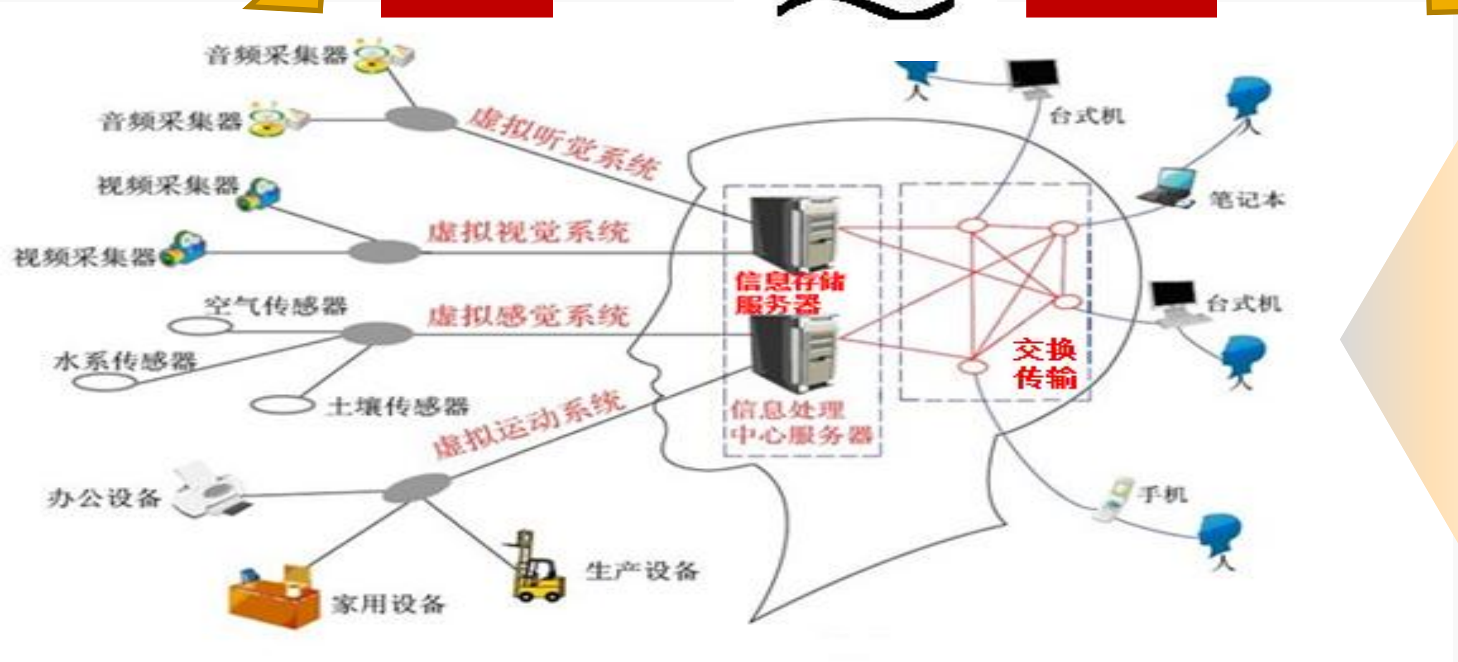
VS

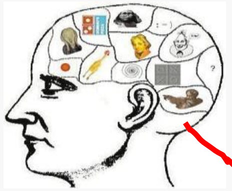


Network:
Signal capturing + accessing + Computing + Rendering

挑战：

Human ≈ Netwrok





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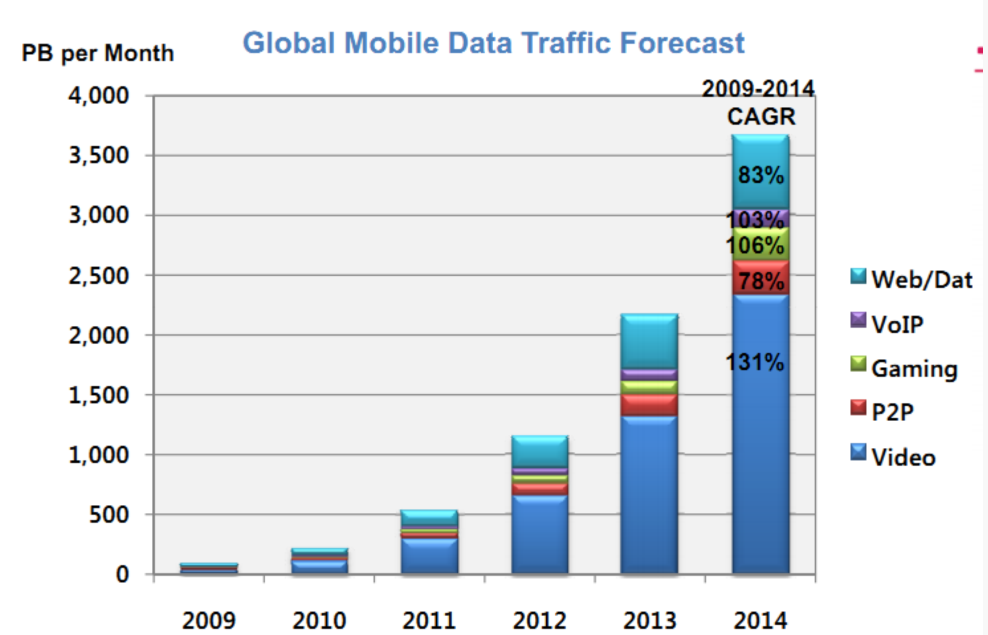
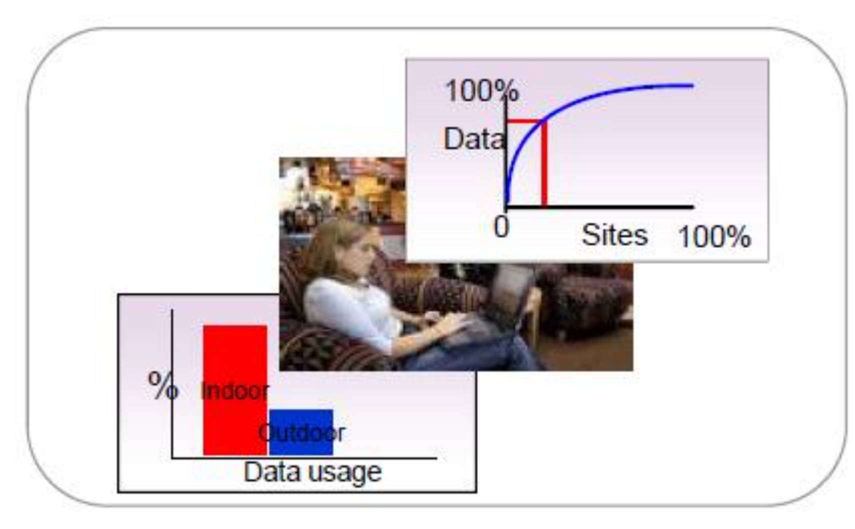
Network traffic Challenge: 1000X





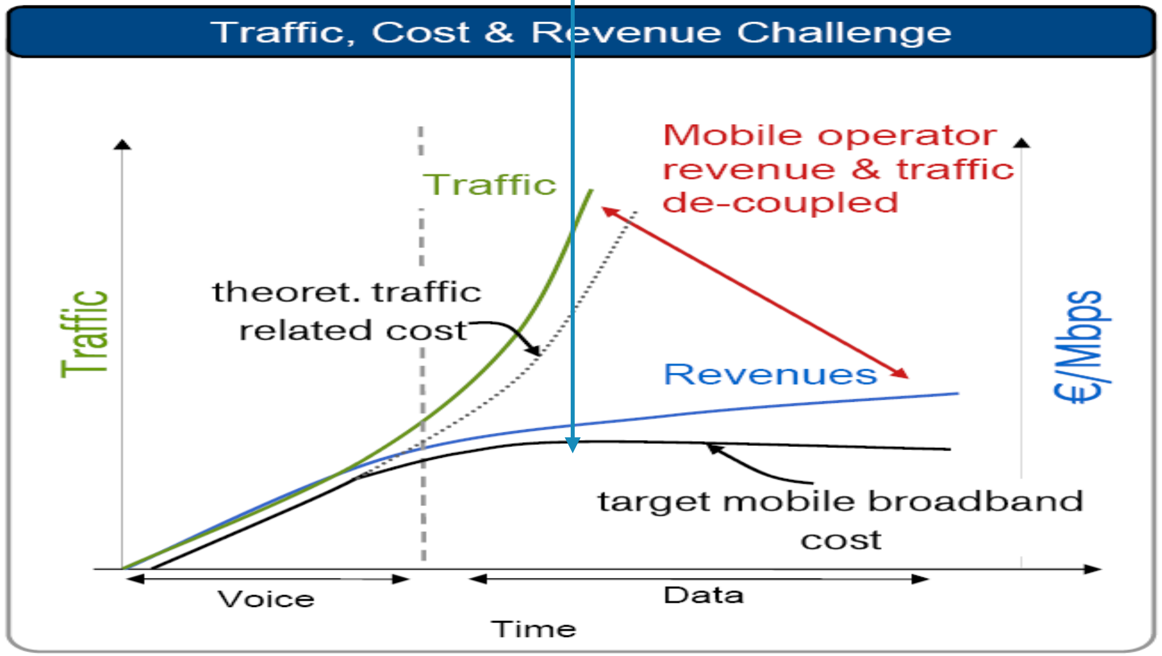
Source：Cisco Visual Networking Index: Forecast and Methodology, 2009-2014, 2010.6

If indoor traffic occupies 70%, outdoor capacity still need increases 300X

Capacity= #sector*BW*Spectrum Efficiency

Cost Challenge: Decreasing the bit transmission Cost

Gross profit=(ARPU—Monthly Traffic Volume*MB Unit cost)/(Monthly Traffic Volume*MB Unit cost)



$$MByte\ TCO = \frac{site\ TCO\_per\_day}{(BW \times Spectrum\_eff \times 3600)/BHR}$$

Busy Hour Traffic Volume

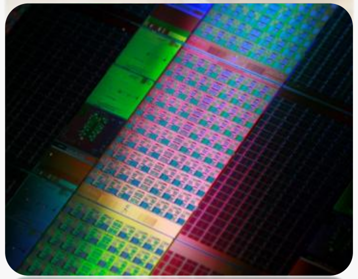
Volume in one day

- **BHR: traffic in busy hour / traffic in one day**

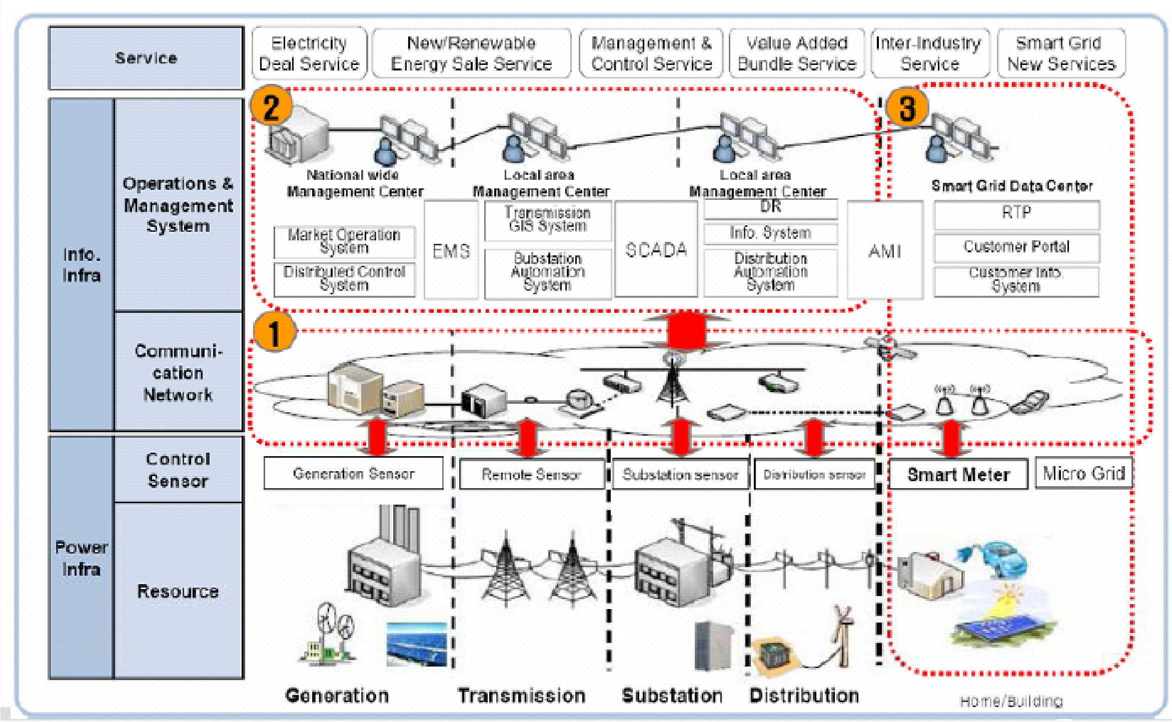
Experience Challenge: Sustained QoE/QoS

Superlative experiences will win customers



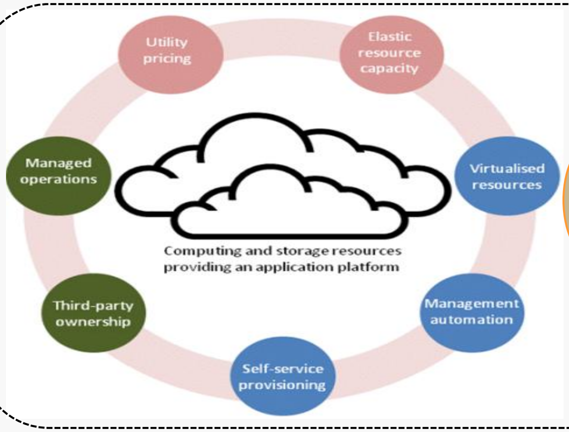
bandwidth， delay

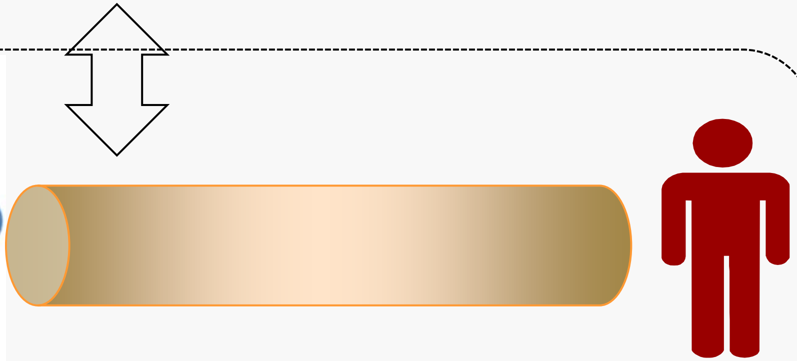


Small volume, but low delay

Challenge in network delay

Latency of network less than latency of Human response (117ms)





Human

Visual： 150ms

Touch： 117ms

Hear： 120ms

摘自人体反应时研究文档

Energy Challenge

- Global scale:
  - Energy consumption of ICT not neglectable (2% of CO_2-emission)
  - 3G Basestation example
    - RF output @antenna : 60W
    - Power input: 1000W (Efficiency 6%)
    - Design for spectrum efficiency, Not Power efficiency
  - Electricity Bill
    - 1W*1year= 8.6 KW*h
    - 1,000,000 BS in China

Not forget battery of device

- Historical 11% capacity growth
  - Not well matched to Moore's Law
- Continued innovation required just to maintain 11%
  - New Si alloy materials or anode Carbon Nano Tubes (CNT) may help

4.5 kCal
30g

255 kCal
49g

x2.2 Capacity

	2011 Today	2020 11% Growth
mWH	5700	13135
1 day	475mW	1095mW
3 day	159mW	365mW

Assuming 12 hours of use per day

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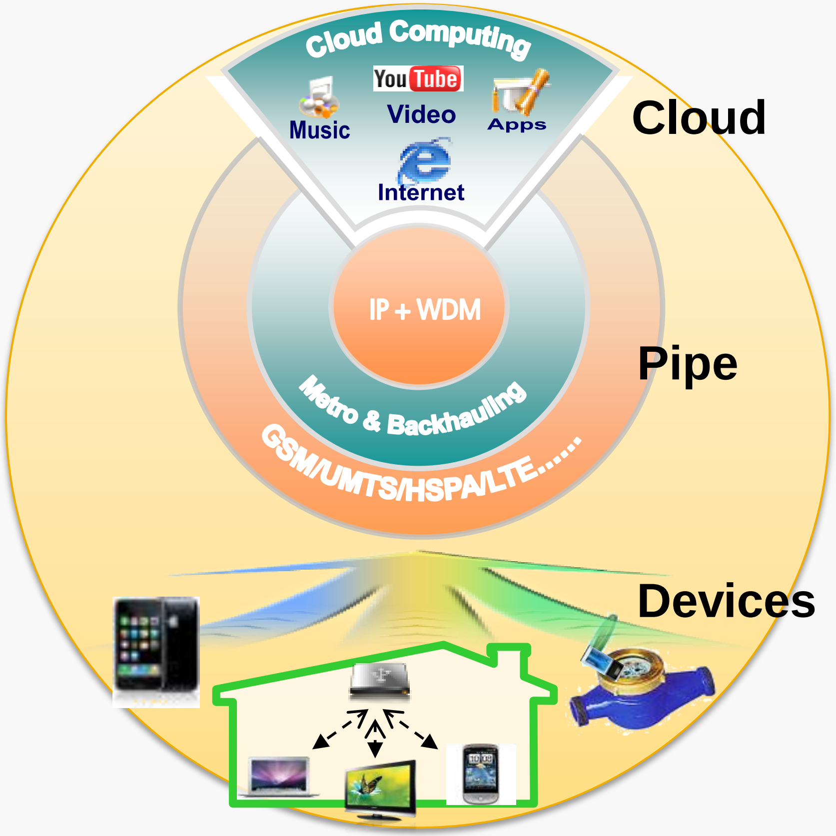
Driving Transformation



Opportunities

- Develop Cloud based services
- Increase 500x capacity and more
- Expand all encompassing mobility

Only by meeting challenges will we realize new opportunities

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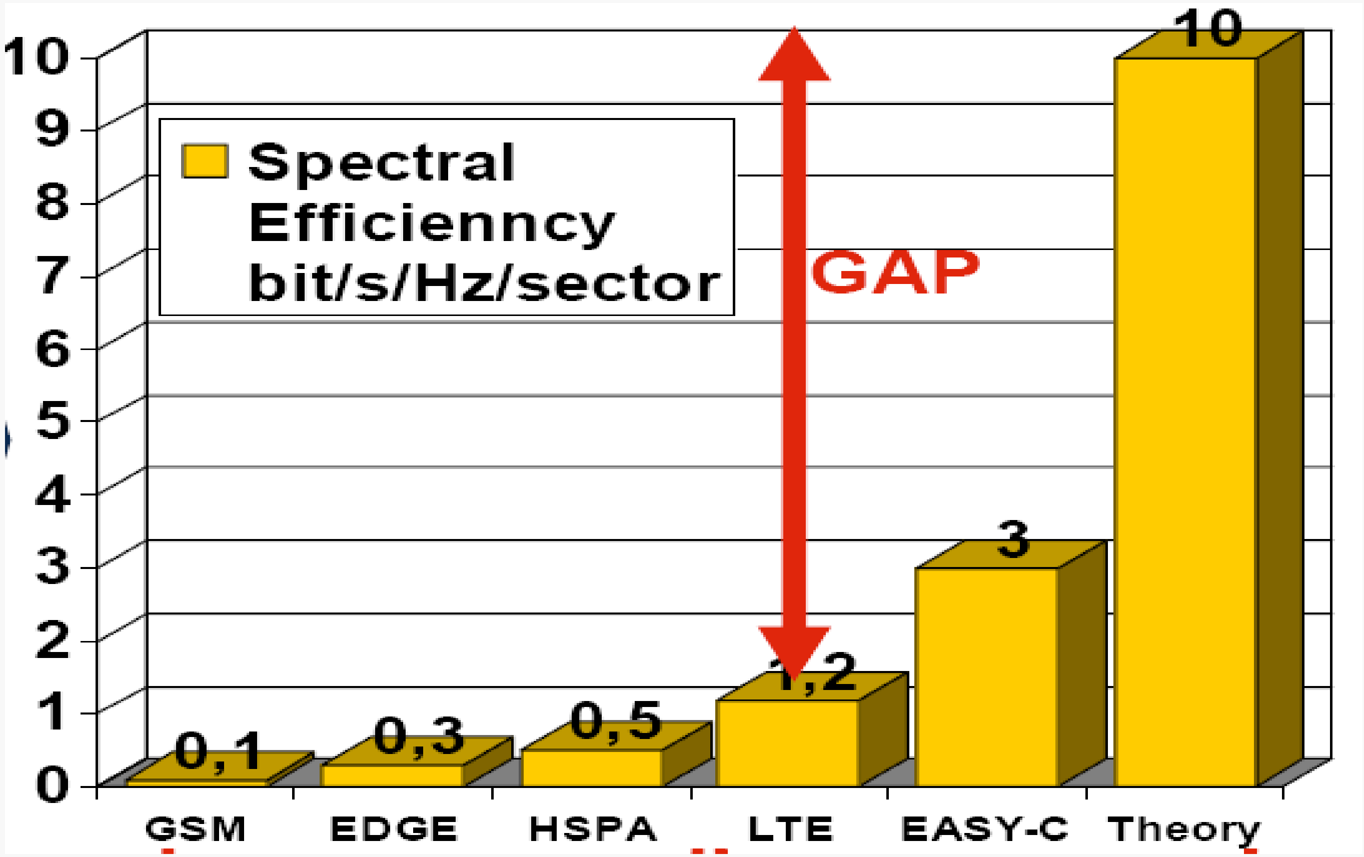
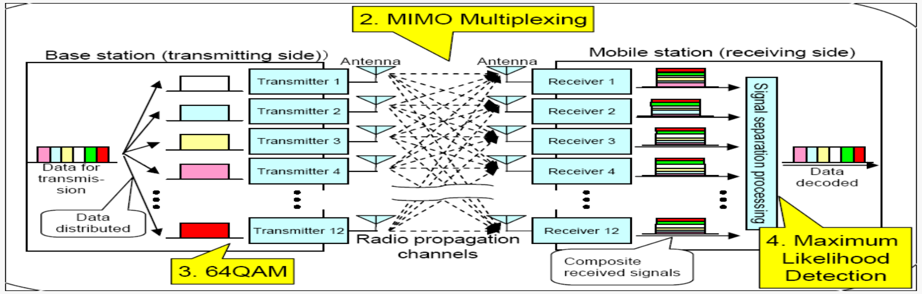
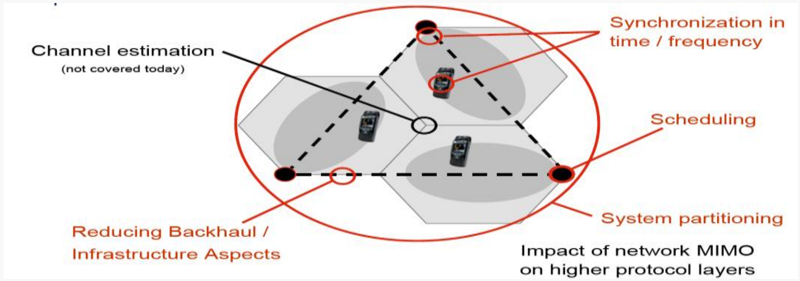
Spectrum Efficiency

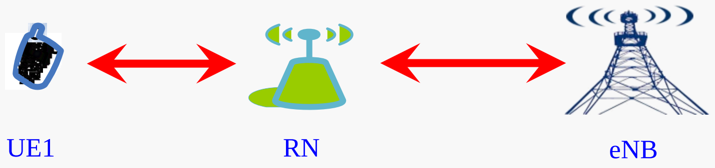




$$C_{MIMO} = Mf_g \log_2\left(1+\frac{S}{N}\right)$$



cooperative



1987 → 2007

20 Years

20 Years →

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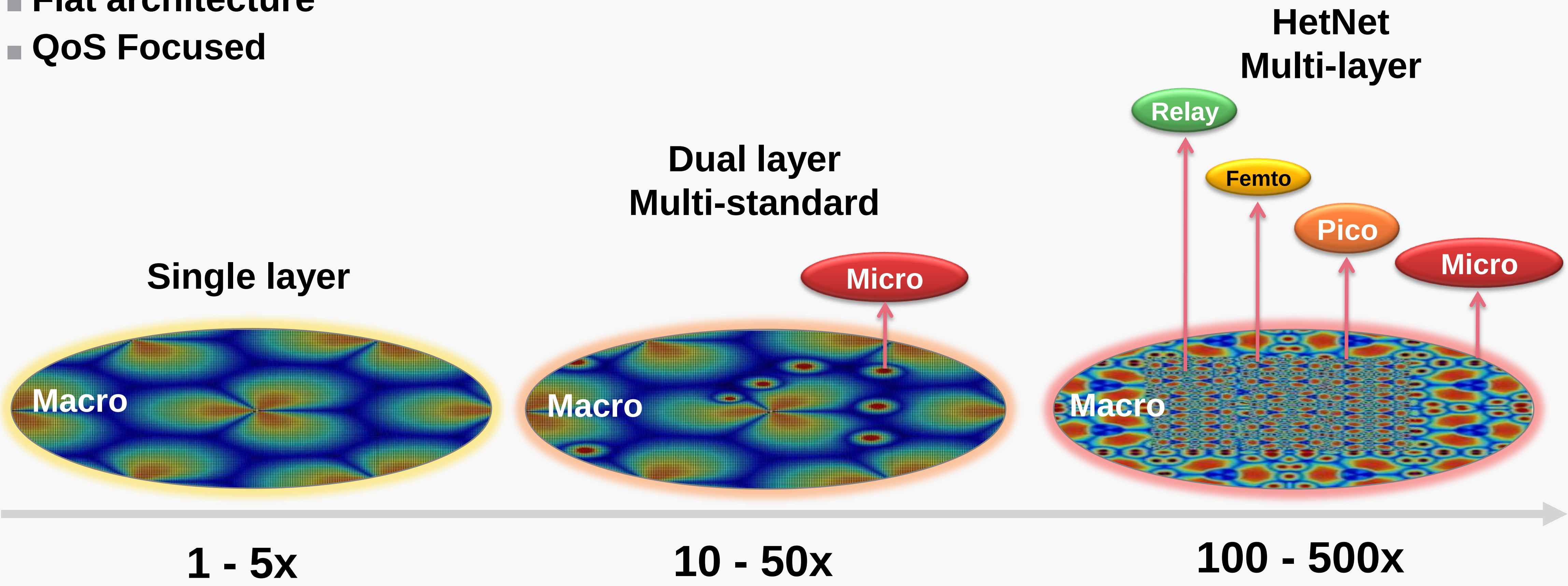
HetNet: A Key for 500x Capacity

- Flat architecture
- QoS Focused

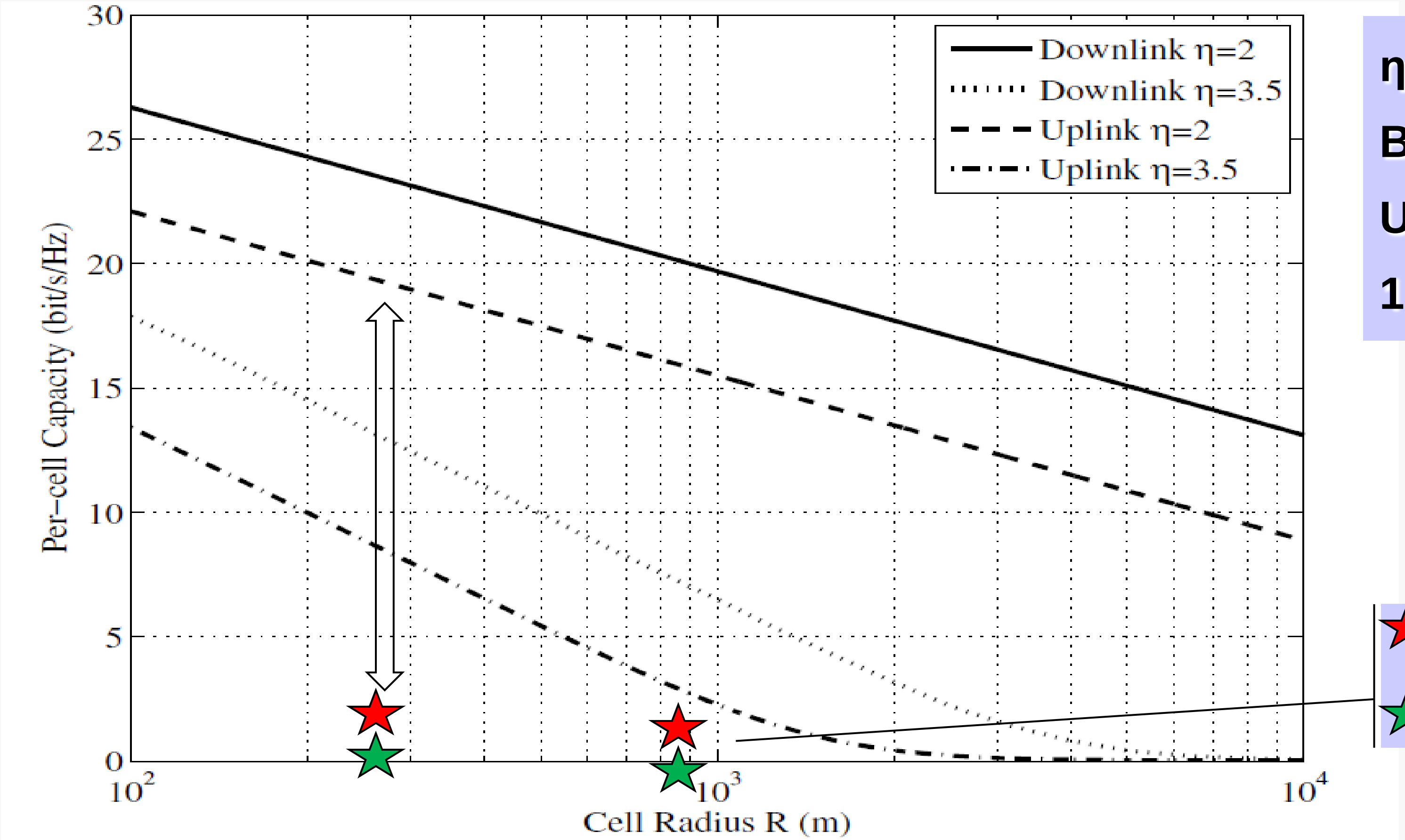


Hyper Transceiver

- Definition:
  - All transmitters jointly transmit signals
  - All receivers jointly decode received signals
- In cellular system, if UEs do not exchange information
  - For UL, all BSs jointly decode all UE's transmission → Hyper Receiver
  - For DL, all BSs jointly encode all UE's transmission assuming known UE's channel knowledge (for example, DPC) → Hyper Transmitter
- When UE can share the info, e.g., via D2D (WiFi), true hyper transceiver is feasible
- With distributed BS architecture, JP CoMP is a form of Hyper Transceiver
- Combining centralized network architecture (such as C-RAN, BBU hotel) with D2D cooperation, Hyper Transceiver could be the key enabler to optimize spectrum efficiency

Theoretical Capacity of Hyper Transceiver

Cellular system without UE cooperation



η : Path Loss Exponent

BS transmit power : 50W

UE Transmit power: 200mw

16 UE Per cell

DL: 2.5 bit/s/Hz, 2x2

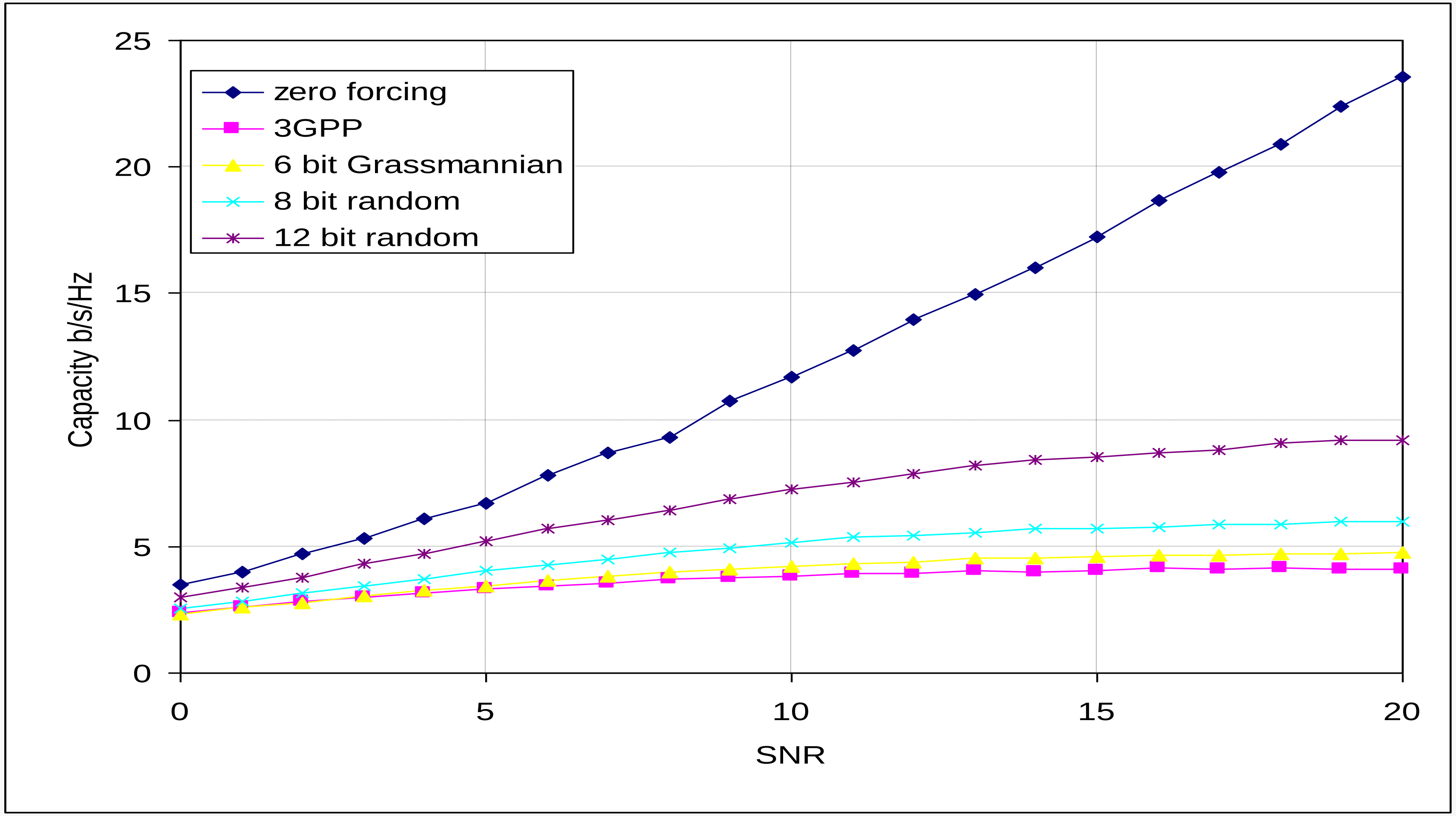
UL: 1.6-1.8 bit/s/Hz, 1x2

Large potential exists for spectrum efficiency enhancement with Hyper Transceiver, key challenge is how to realize it practically

Known Ingredients

- MU-MIMO
- Interference Alignment
- Dirty Paper Coding
- Successive Interference Cancellation
- CoMP

MU-MIMO



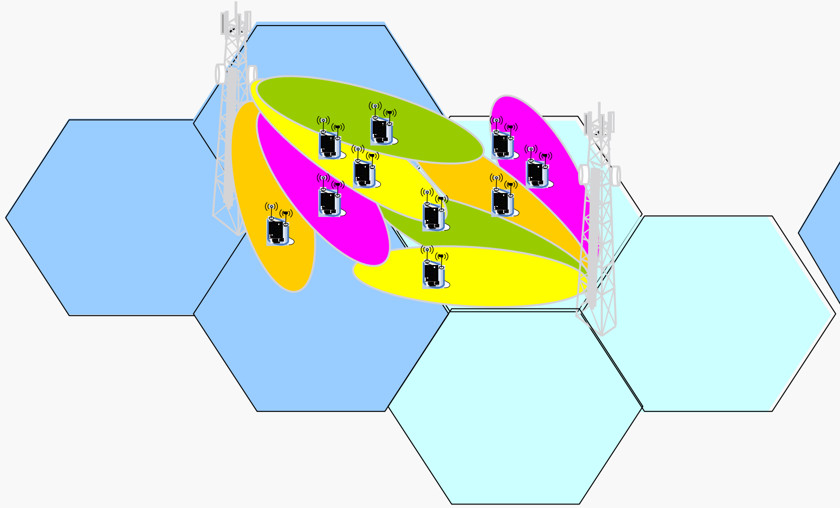
Sum capacity performance of MU-MIMO with the number of users = number of antenna = 4 for the Grassmanian, random and 3GPP LTE base codebooks.

MU-MIMO Issues

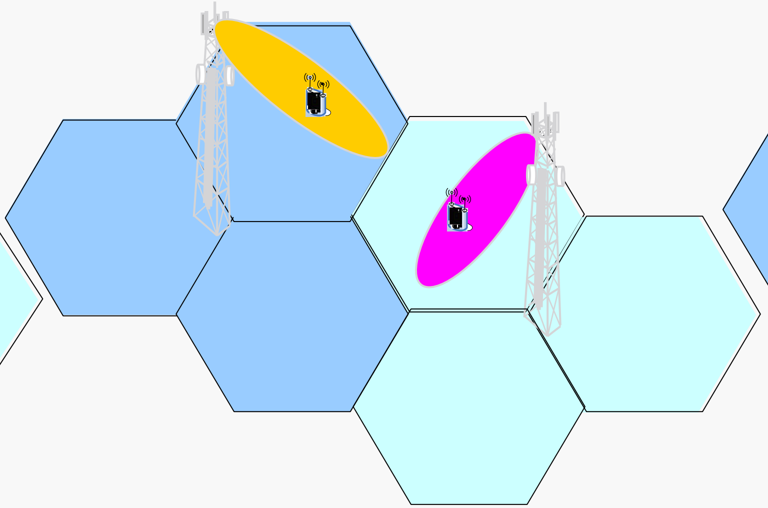
- DL MIMO
  - Rel-8 codebook design is far from optimized
    - Codebook optimized for linear array type of antennas
    - Limited resolution due to feedback overhead consideration
  - Implementation complexity for user paring
  - Neighboring cell Interferences limit SINR, hence limit the gain
  - The number of antennas for one BS is limited
- UL MIMO
  - Limited number of receive antennas for one BS
  - Neighboring cell Interferences limit SINR, hence limit the gain
  - SIC receiver complexity

DL CoMP

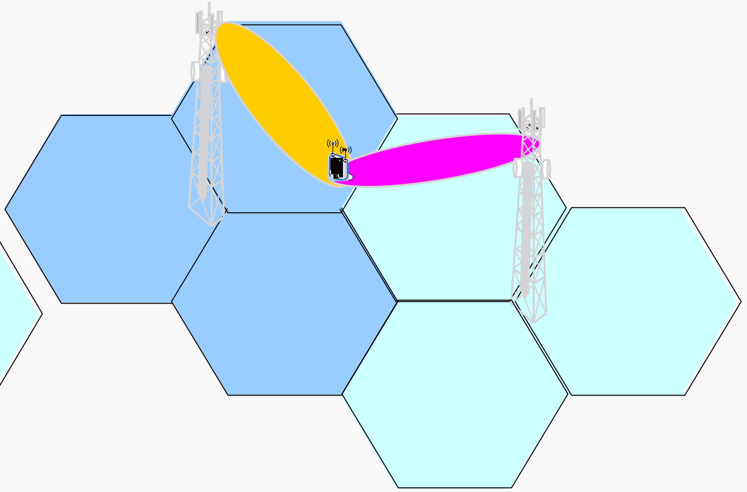
- DL CoMP candidate technologies mainly target CL transmission scenarios where power domain cooperation transmission is less effective.
  - ➔ DL Coordinated MIMO
- From power domain coordination to spatial domain coordination
  - ➔ CBF and CBS
- From single cell MU-MIMO to multiple cell MU-MIMO
  - ➔ CBF, JP
- From single point transmission to multiple point transmission
  - ➔ JT



Coordinated beam switching (CBS)

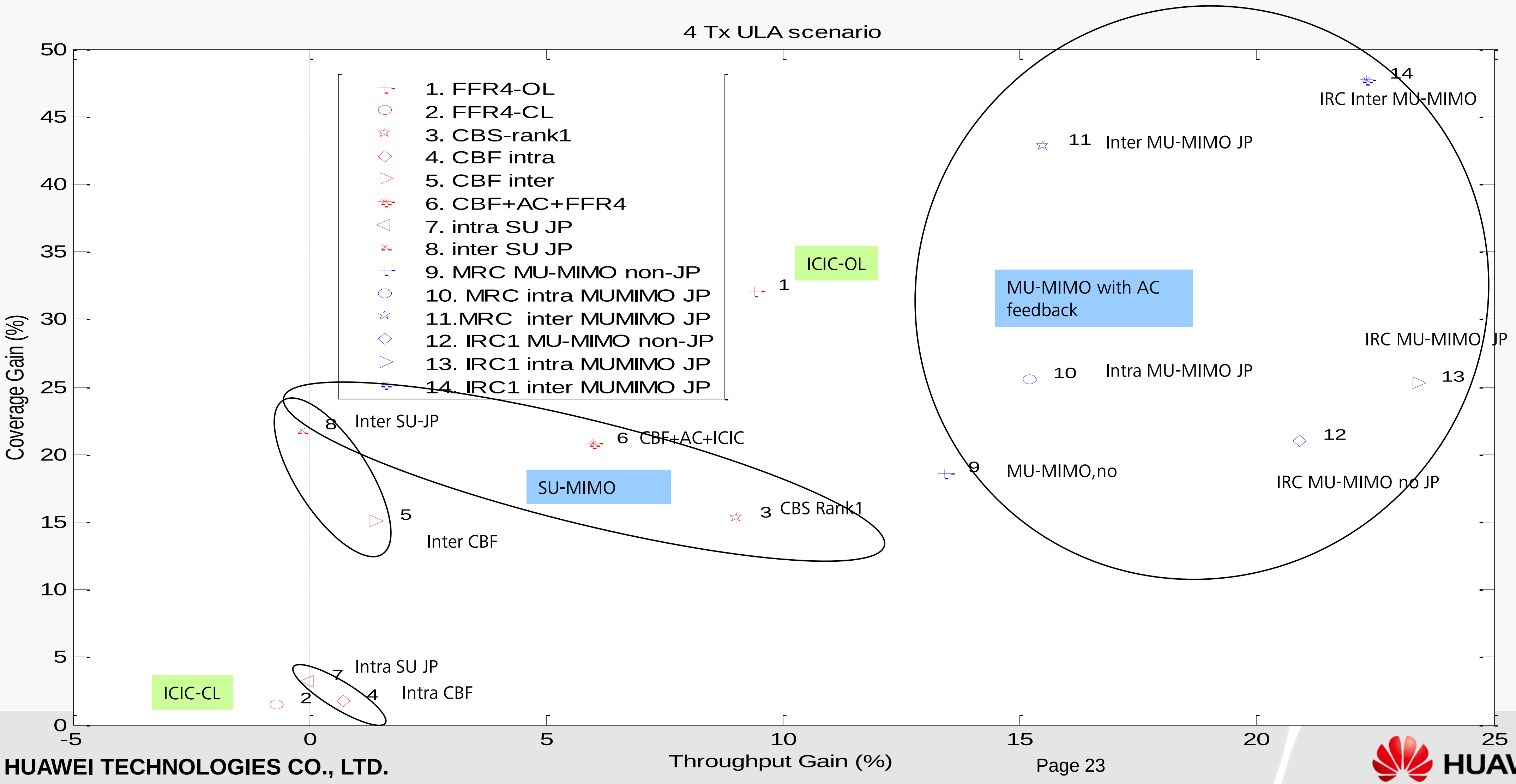


Coordinated beamforming (CBF)



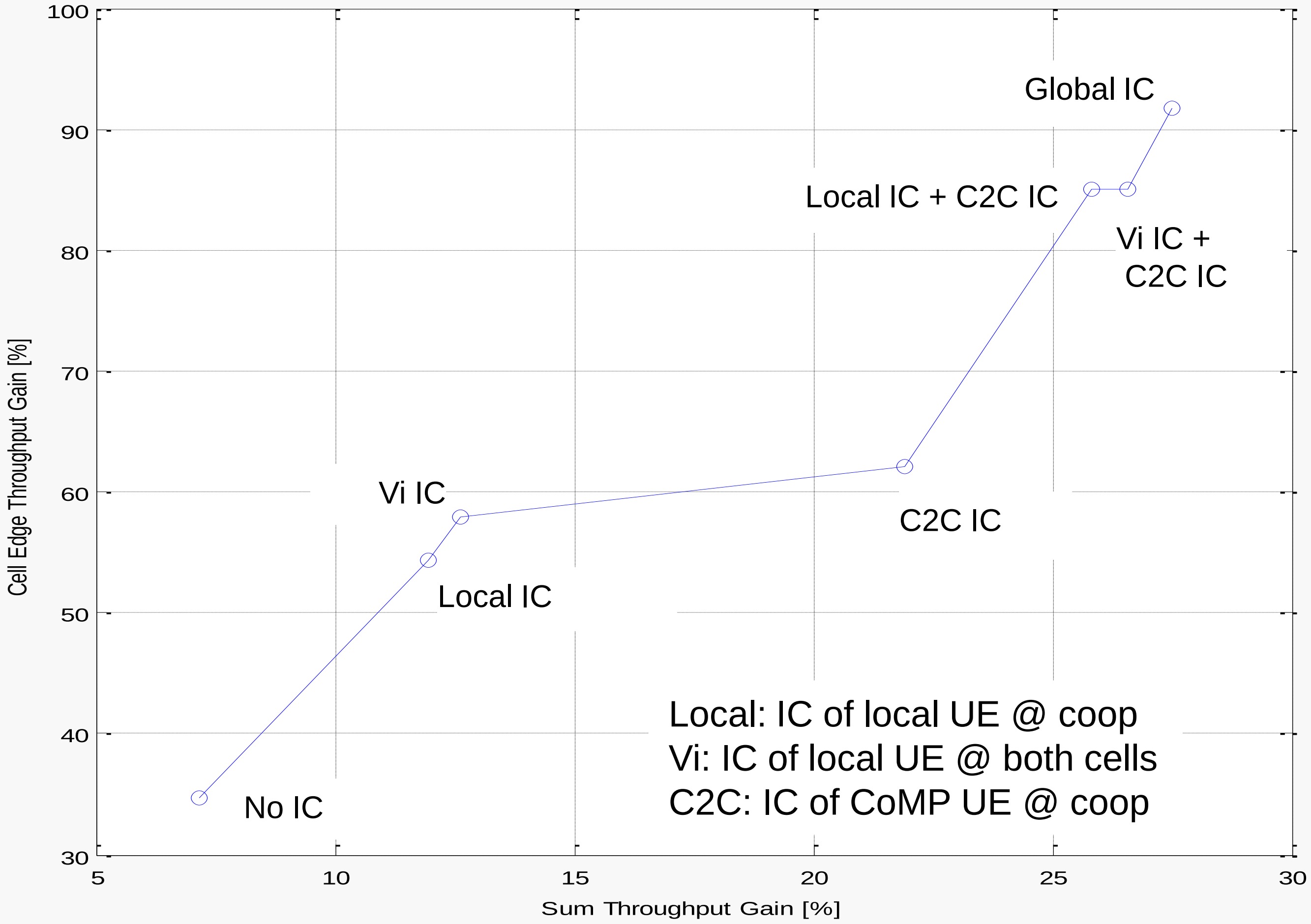
Joint processing (JP)

Overview of DL CoMP Performance
(4 Tx ULA)



Performance comparison of different IC/MRC techniques

Ideal channel estimation (CE) and ideal IC

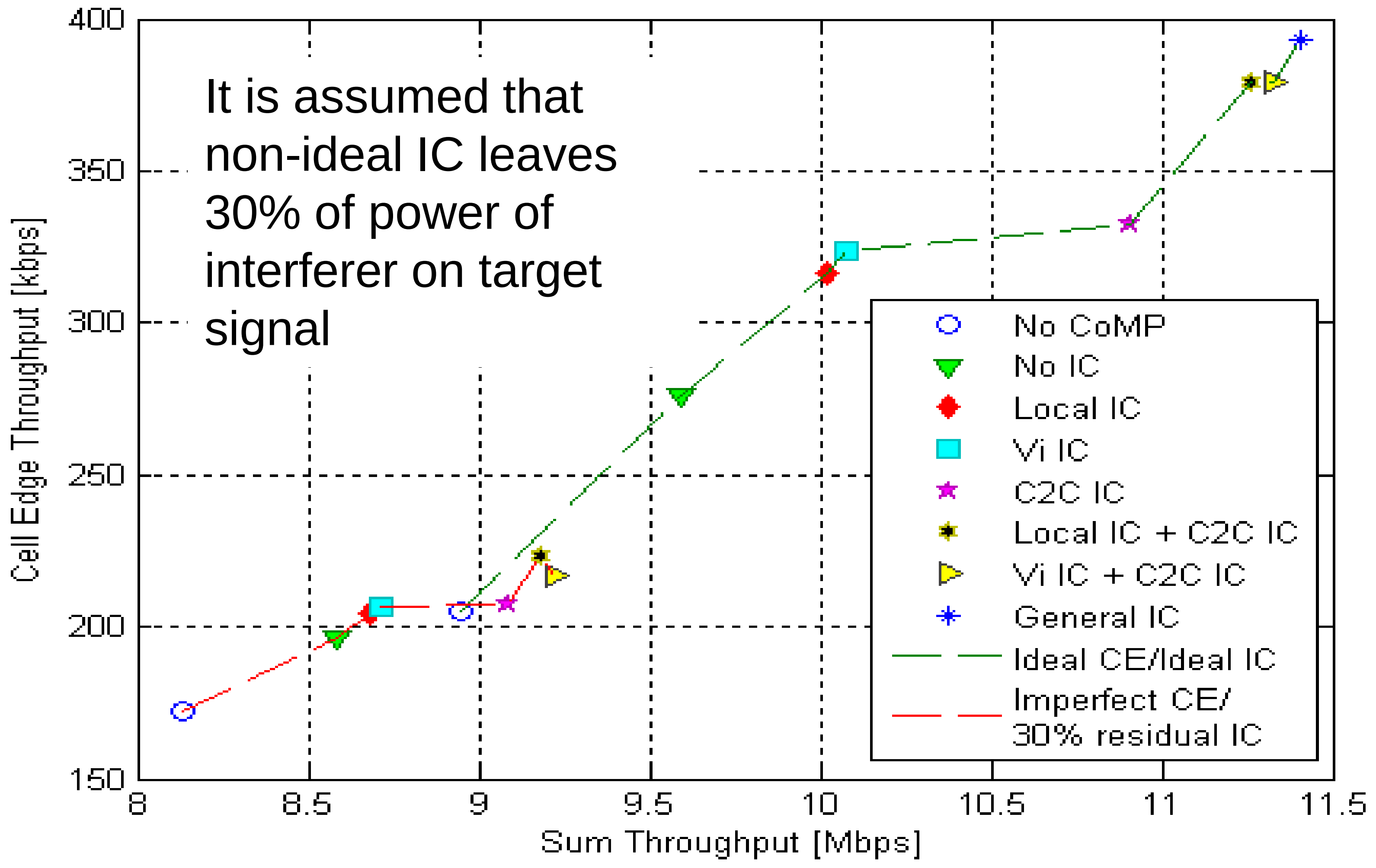


- Vi IC/MRC does not provide extra gain compared to local IC/MRC while Vi IC requires extra backhaul traffic to transfer information of local UE to serving cell

- No IC/MRC, local IC/MRC and local IC + C2C IC/ MRC are the reasonable candidates

Impact of imperfect CE/IC on performance

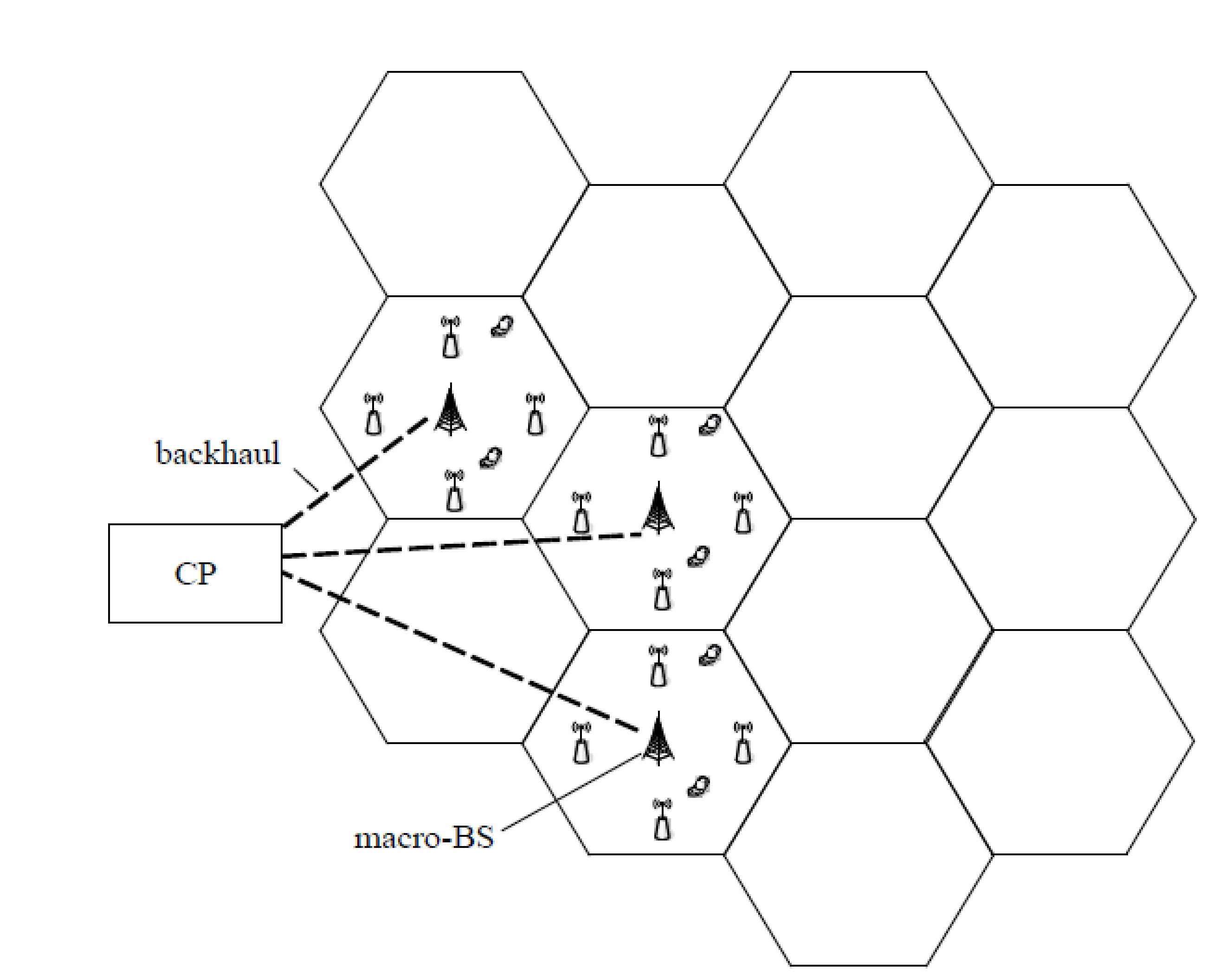
IC/MRC techniques



- Big gap between performance with ideal and non-ideal channel estimation
- Room to improve PHY detection techniques for future work

Local: IC of local UE @ coop
Vi: IC of local UE @ both cells
C2C: IC of CoMP UE @ coop

Network MIMO的支撑技术



- Network MIMO需要中心处理（CP），BS到CP数据传输及AP到BS的传输成为关键问题
  - Fiber
  - DF（Decode-and-Forward）
  - CF(Compress-and-Forward)
  - 混合模式？

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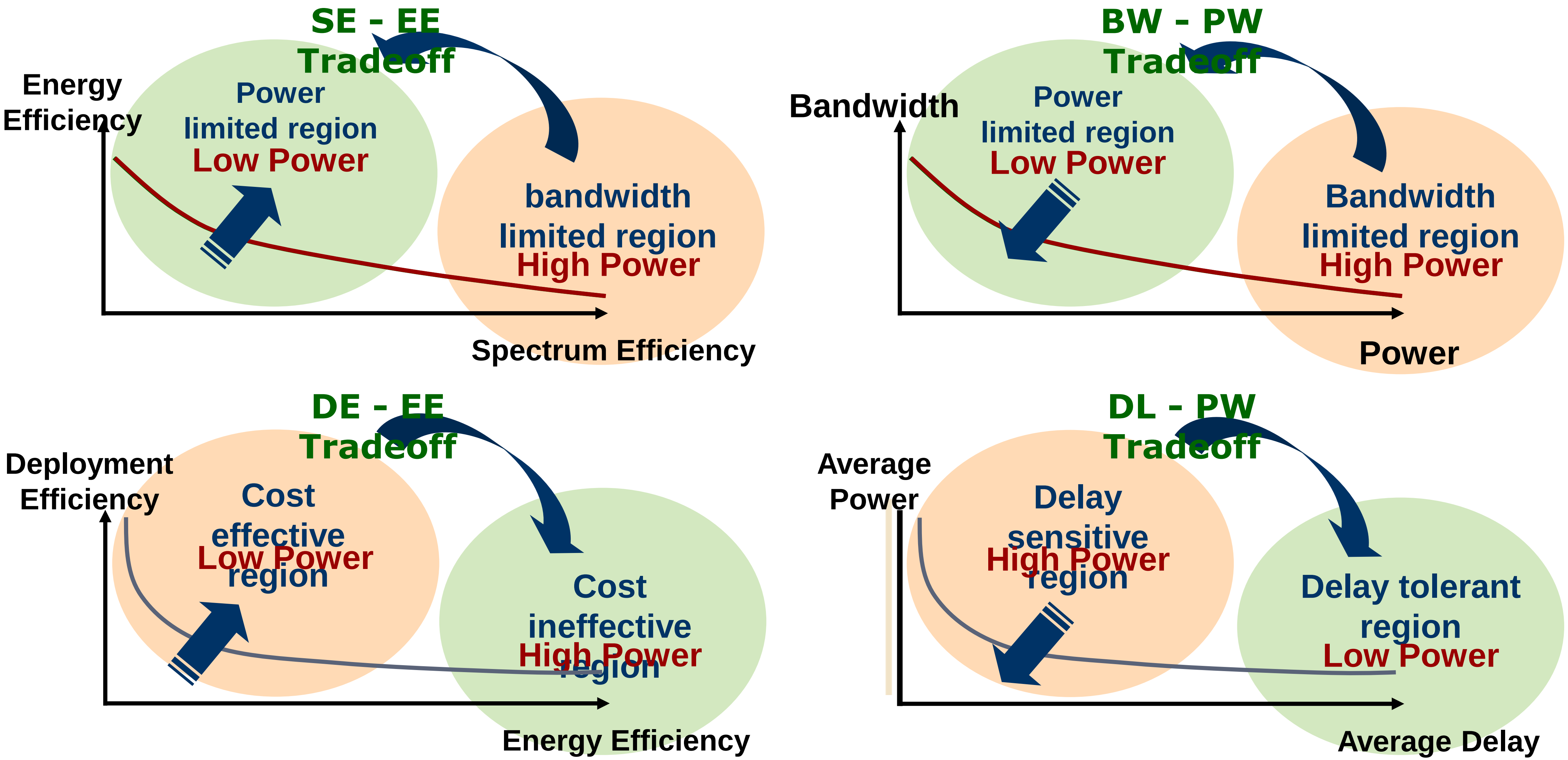
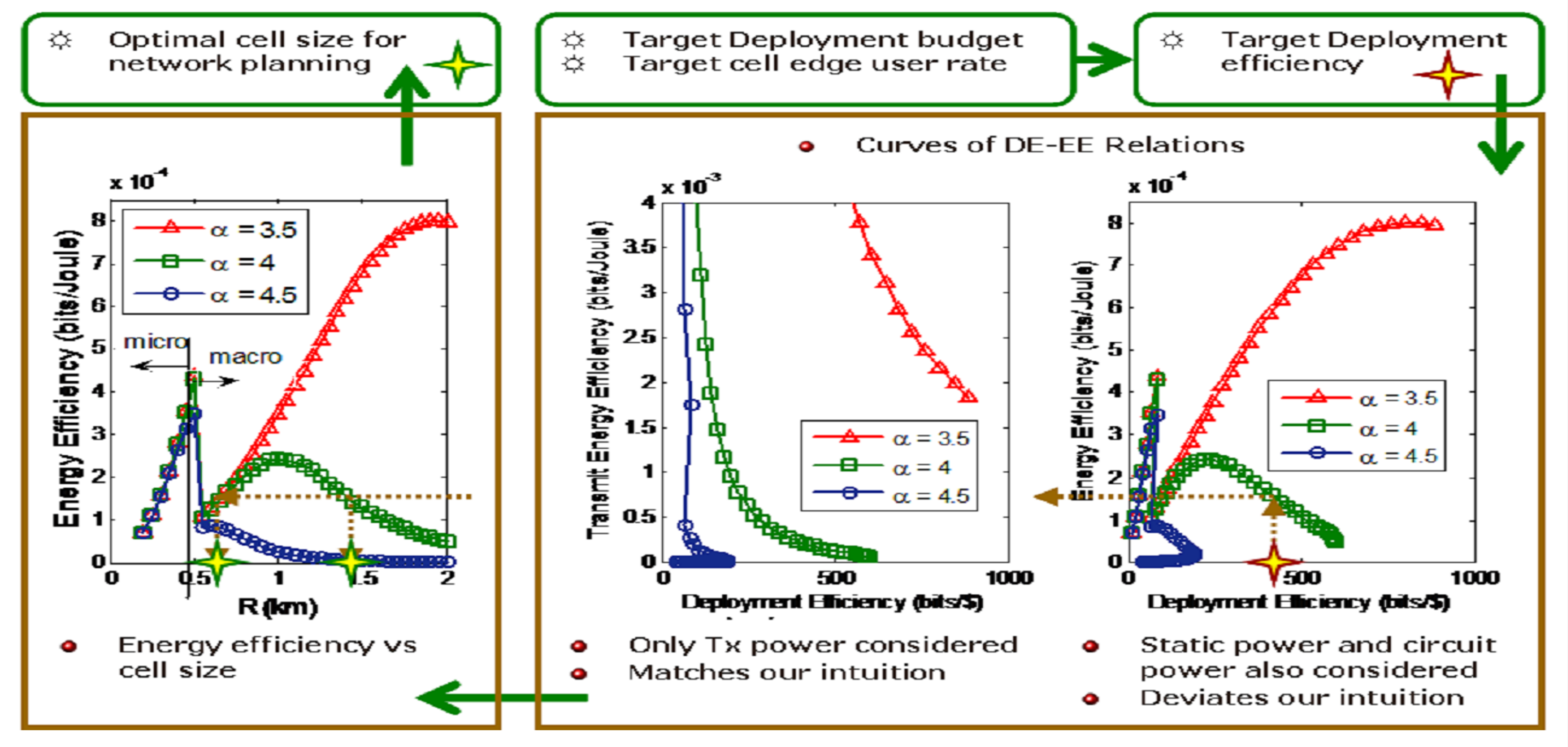
Green Radio : Insight from Shannon

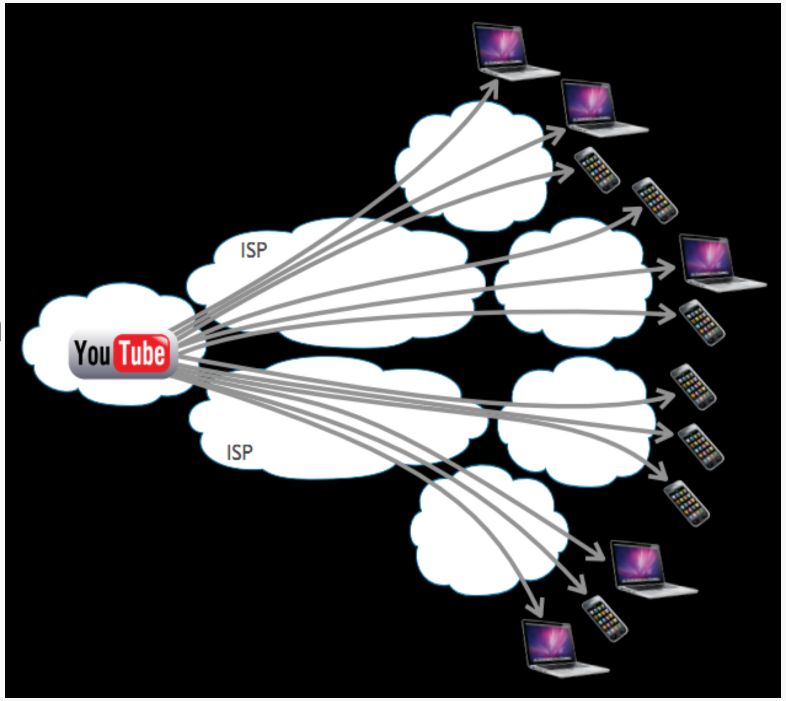


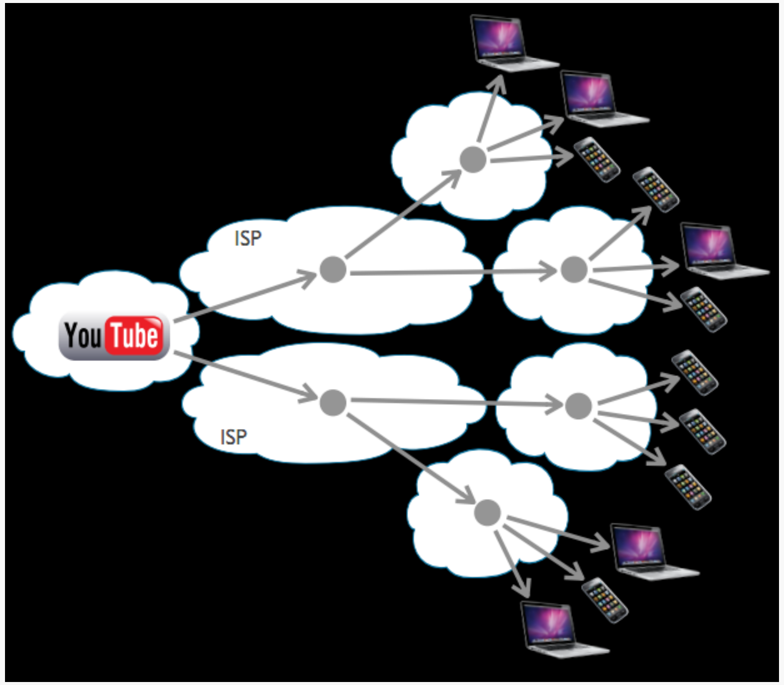
Guidelines for Energy Efficiency Radio Access Network Design



Content Oriented Network Architecture (CONA)

- Mobile Storage rapidly increasing, lower cost (Flash <1$/GB).
- Always connected and everything stored centrally OR Everything in devices?
- New storage based system paradigm
- CONA is a networking architecture optimized for content storage and dissemination, the most similar works with CONA is the CCN (led by Van Jacobson) and EU FP7 4Ward NetInf.
- Basic idea is Content naming and Routing.





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