Innovations in Spectrum Efficiency

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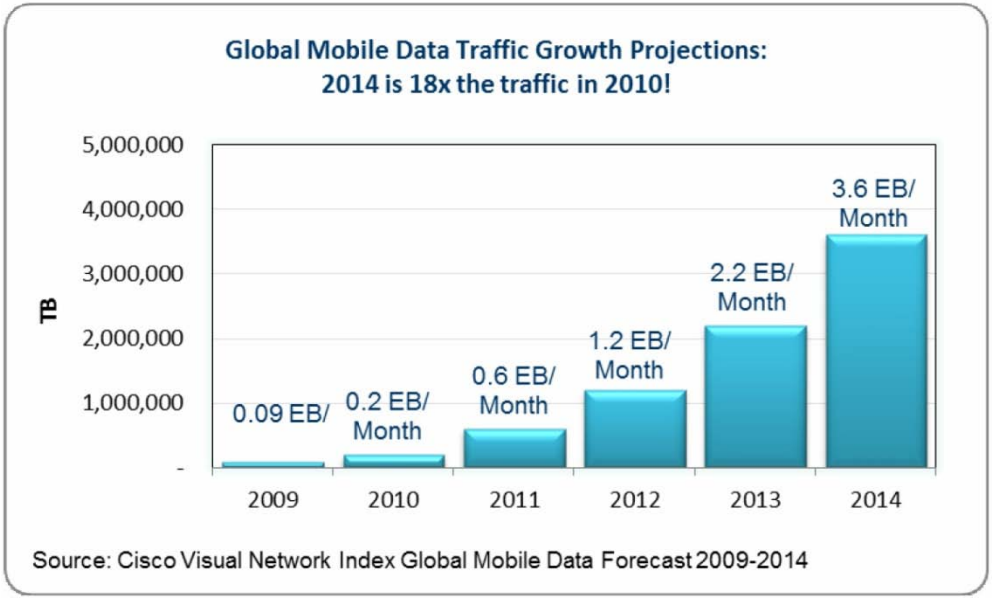
The Challenge: Spectrum Efficiency

- "***Our members, though diverse, share one common goal: effective and efficient management of the radio spectrum***"

  Kenneth G. Ryan, P.E
  President – NSMA
- **FCC (and other regulators worldwide) still offer the same spectrum resource while data usage is growing exponentially**



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How Do Regulators Promote Spectrum Preservation?

- **FCC:**
  - Stringent spectrum efficiency rules at 6, 11GHz
  - Frequency diversity is not allowed
  - N+1 restrictions (N≥3)
- **Other regulators:**
  - The wider the channel – the more you pay
  - The lower the frequency – the more you pay

Freq.	14MHz	28MHz	56MHz
6GHz	**€ 2,125**	**€ 4,210**	**€ 8,380**
11GHz	**€**123	**€** 206	**€** 372
23GHz	**€** 85	**€**131	**€**221
38GHz	**€** 63	**€**85	**€** 131

  - License fee based on distance
  - Defining minimum distance per frequency band
  - 2+0 using XPIC paying less than two channels
  - Rebate scheme for channel reuse

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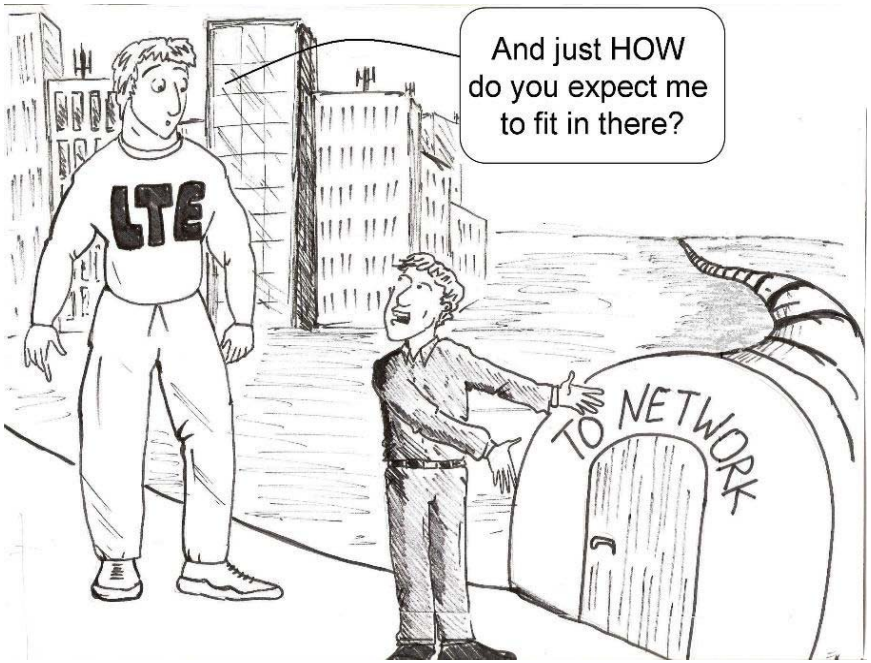
And just HOW do you expect me to fit in there?
LTE
THE
BIGGEST
LOSER
TO NETWORK

Extracting More Bits from a Given Channel



- **Higher Order of Modulation & Coding**
- **Compression**
  - Header compression
  - Payload compression
  - Idle suppression
- **XPIC (CCDP)**
- **Native Ethernet Transport**
- **Adaptive Power ACM (Adaptive coding/modulation)**
- **Adaptive Bandwidth Recovery (ABR)**
- **Asymmetric Transport**

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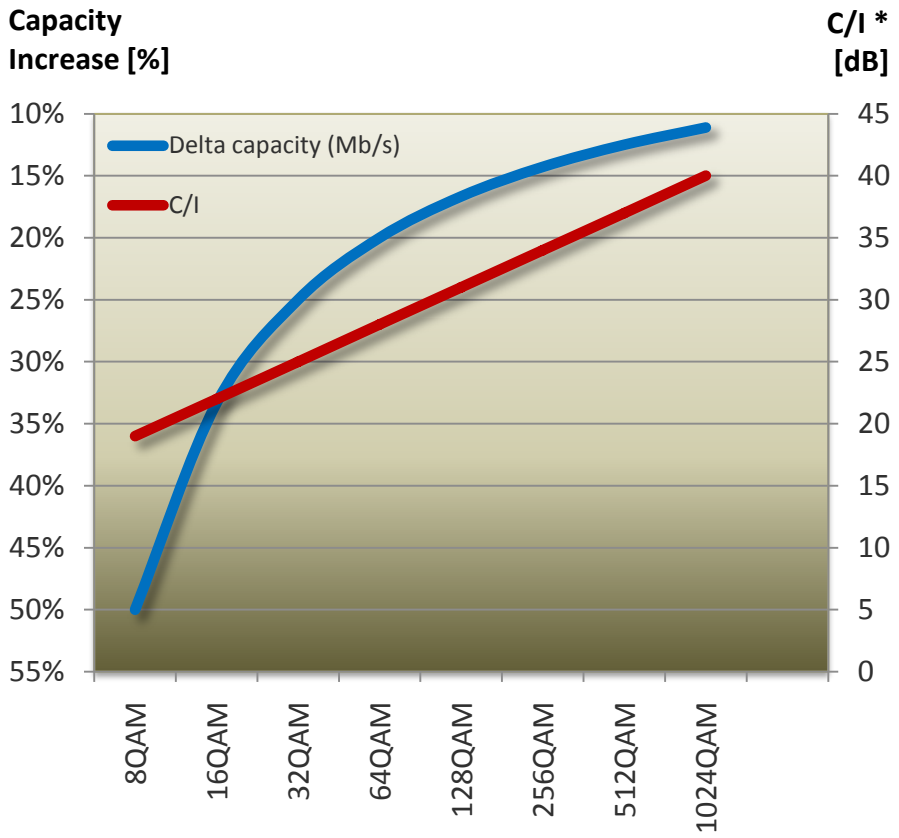
Meeting the practical limits of physics



- **Increasing modulation complexity meets natural limits**
- **From 256 to 1024 QAM, capacity increase is theoretical 25%** **(assuming no additional coding)**
- **System gain penalty about 7dB**
- **Requires "interference free" environment - can it work in field?**

*: typical figures for 1dB threshold degradation

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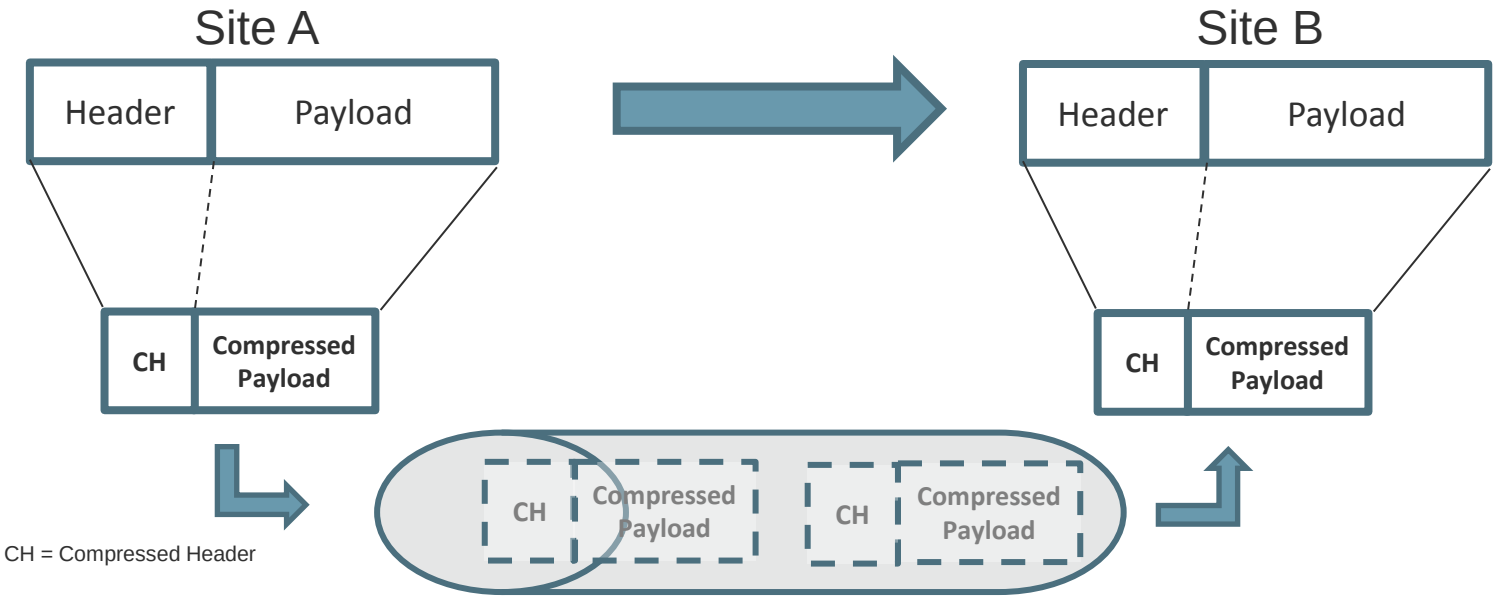
Enhanced Compression over the Backhaul

- **Multi-Layer Header Compression**
- **Payload compression**



Up to 150% more capacity - at no extra cost!

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3GPP Mobile backhaul Traffic Model 1

VI.2.2.1.1 Network Traffic Model 1

According to 3GPP, the access traffic is composed by conversational (voice), streaming (audio-video), interactive (e.g., http) and background (sms, e-mail). It is known that in wireless network, 80% to 90% of the traffic is conversational, with the average call lasting from 1 minute to 2 minutes. To be able to model this traffic, 80% of the load should be fixed small-size constant bit rate packets, and 20% of load with a mix of medium and maximum size packets. The packet size profile is:

- **80% of the load must be minimum size packets (64 octets);**
- **15% of the load must be maximum size packets (1518 octets);**
- **5% of the load must be medium size packets (576 octets).**

Maximum size packets will occur in bursts lasting between 0.1 s and 3 s.

- Model represents a common distribution of packet size in a real mobile backhaul network
- Smaller packets dominate the distribution (no “large file transfers”)

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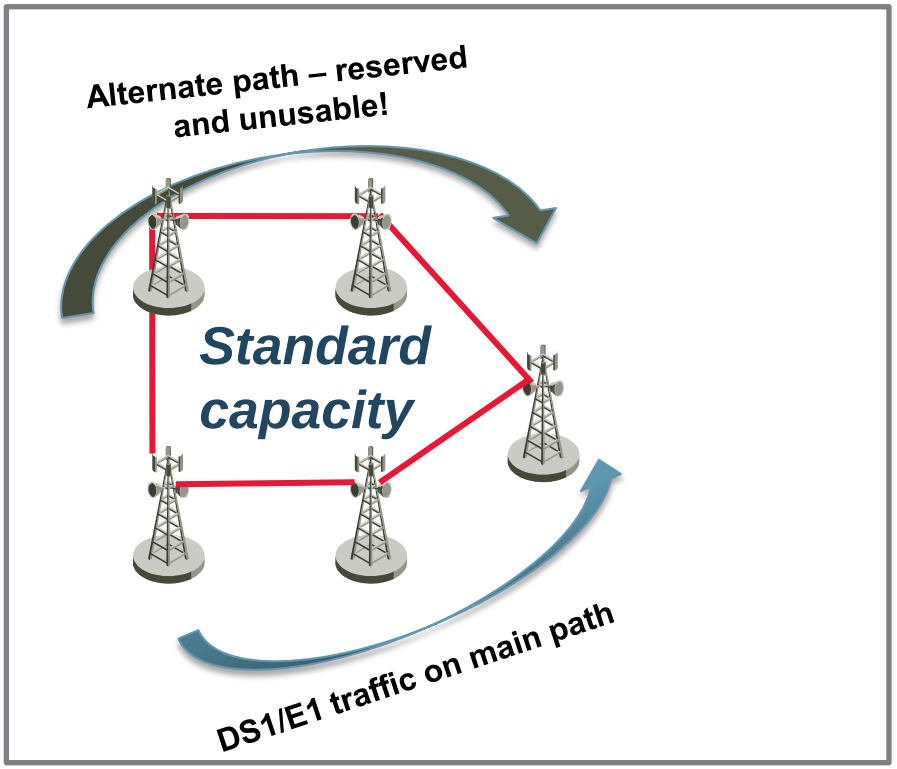
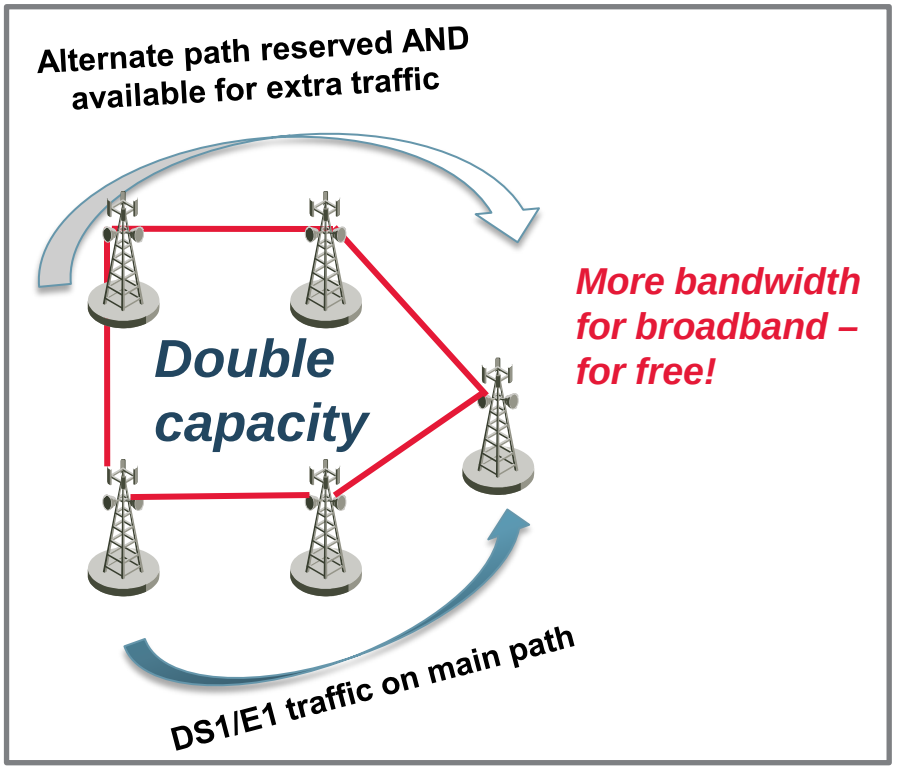
Doubling Ring Capacity

Ceragon's ABR (Adaptive Bandwidth Recovery)

Conventional Protection
(Based on SNCP 1+1)



Ceragon ABR Protection
(Adaptive Bandwidth Recovery)



Double the ring capacity - at no extra cost!

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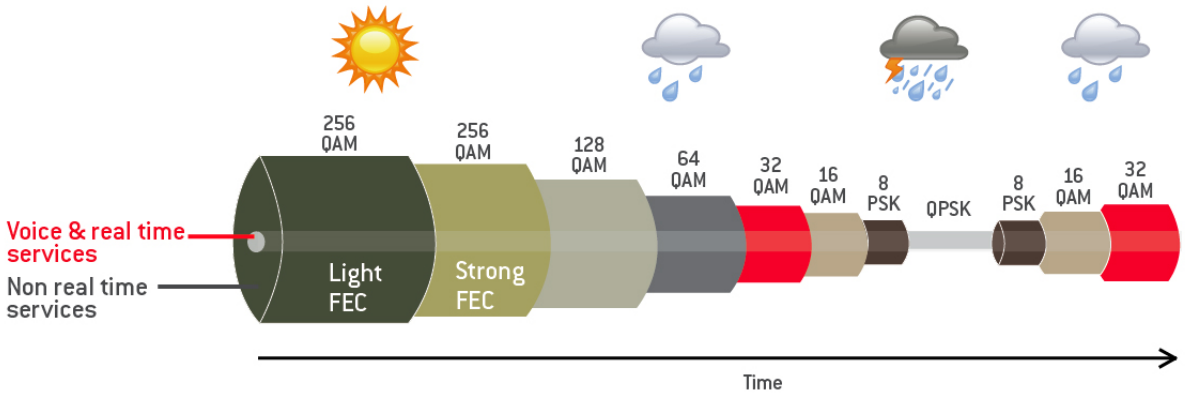
CERAGON

Best Modulation Schemes and ACM

- 8 modulations with robust coding (QPSK – 256QAM)
- Best in Class ACM
  - Adaptive Transmit Power – for higher system gain
  - Flexible prioritization of TDM and Ethernet traffic
  - Integrated advanced QoS engine with Ethernet/IP/MPLS support
  - Unique guaranteed performance (with ACM) 3G/4G synchronization solution
- XPIC & Multi-Radio capabilities for radio carriers aggregation

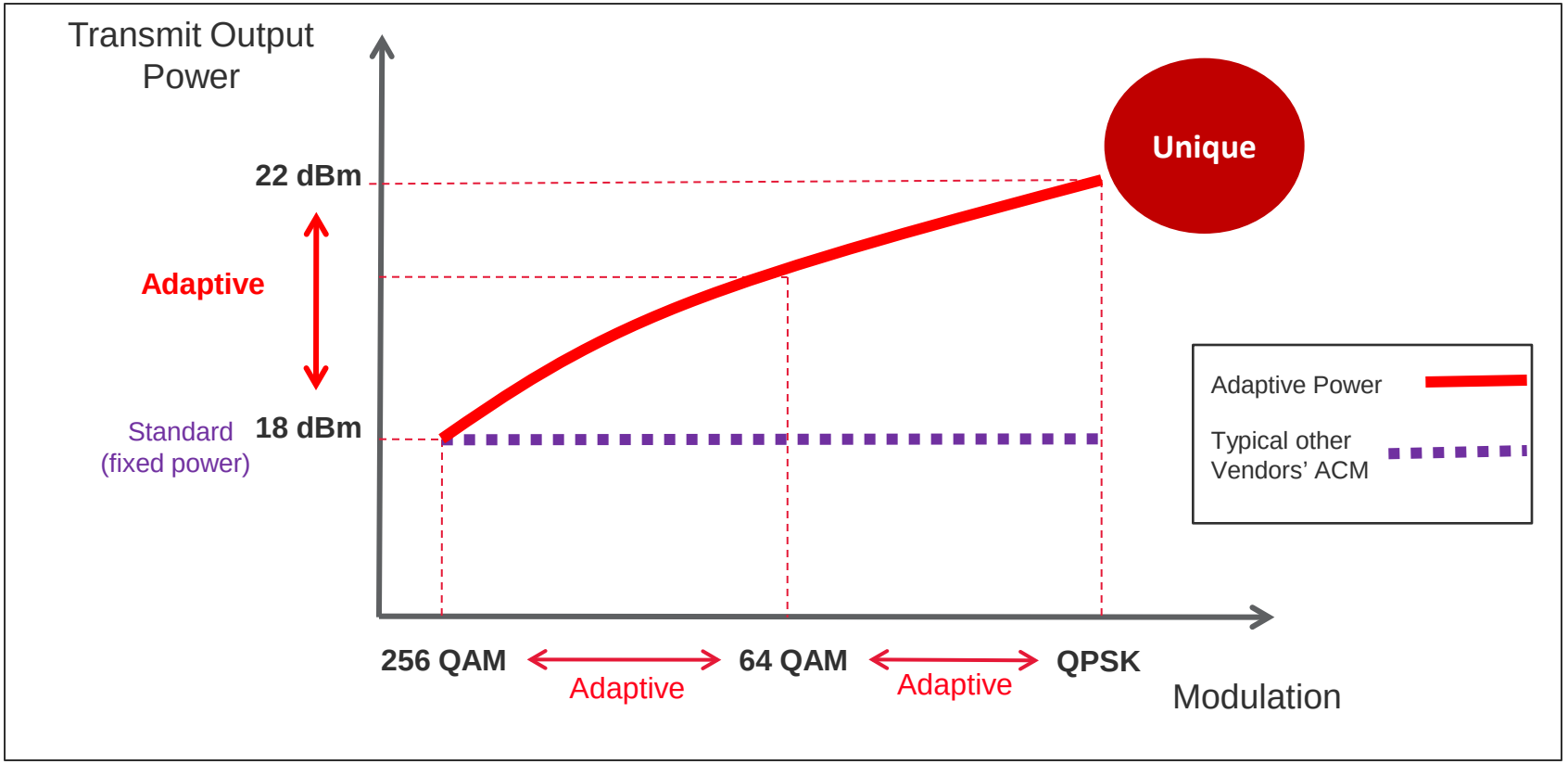


More capacity with higher availability

ACM with Adaptive Power vs. Plain ACM

Availability

Push the envelope further !



Adaptive Power ACM vs. common (fixed Tx power) ACM
example displayed for 18-23 GHz link

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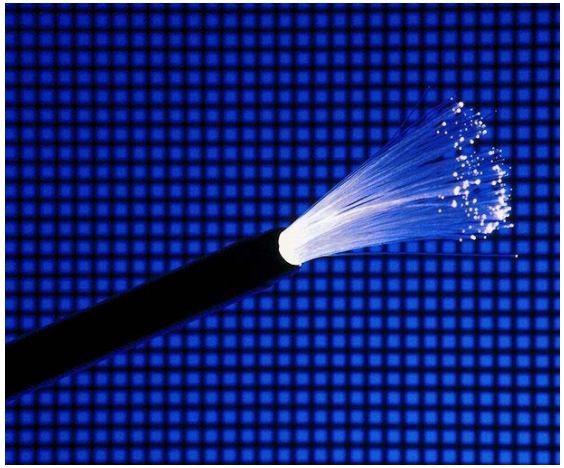
Asymmetrical Links

Transport is symmetric in nature. Really?

Symmetric information
(Voice)



Symmetric media
(Fiber)

Symmetric carriers
(Roads)

What about Wireless ?
Let's rethink this…

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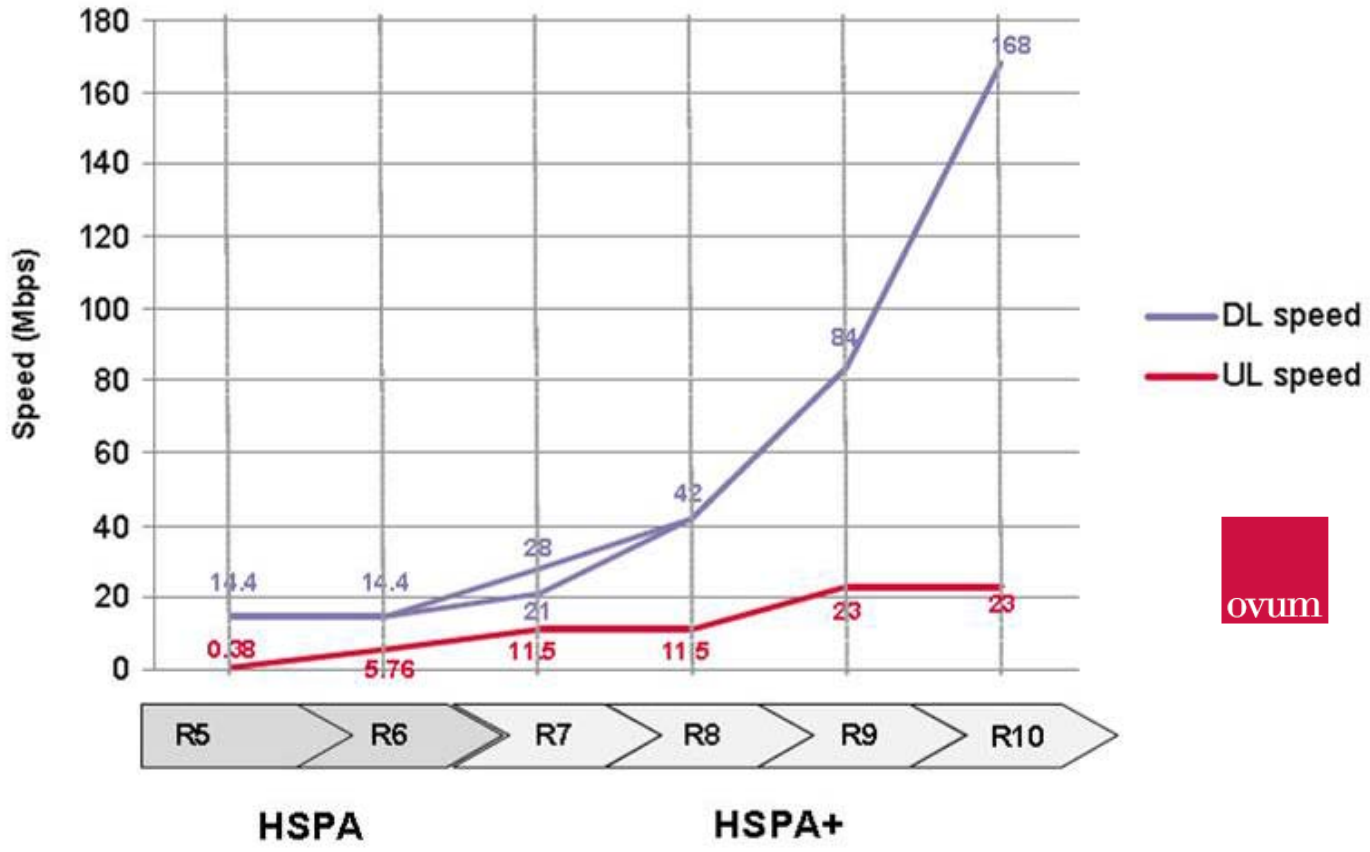
Mobile traffic is asymmetric

Figure 5 **Peak data rate increases brought by HSPA/HSPA+**



Source: Ovum

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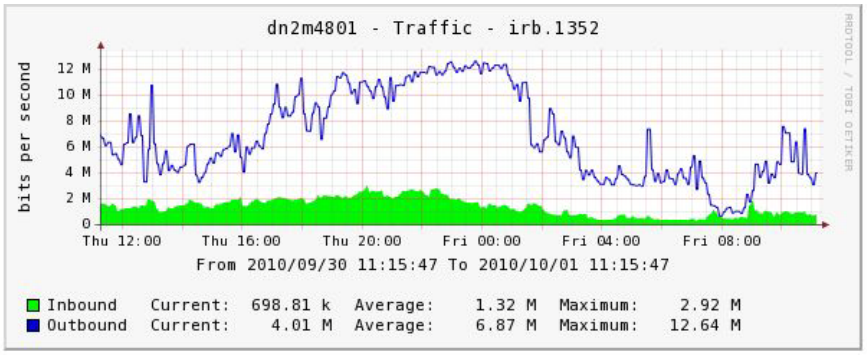
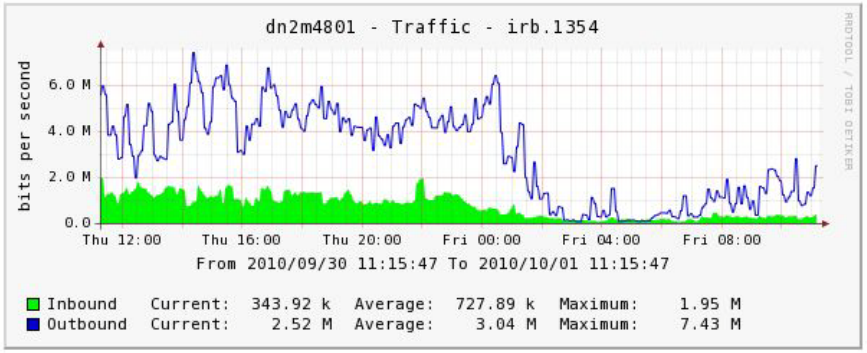
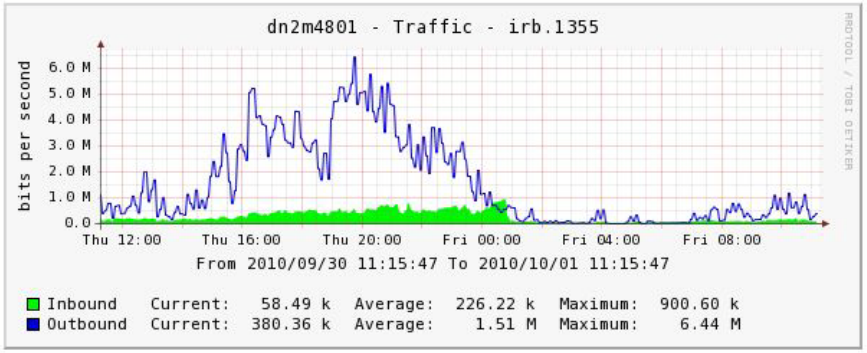
Broadband Wireless is Asymmetric in nature

- **Real traffic capture from a big 3G network operator.**
- **As can be seen the actual Uplink to Downlink ratio is ~1:6**







Asymmetric Transport Intro Clip

Shortcut to asymmetical links .wmv.lnk

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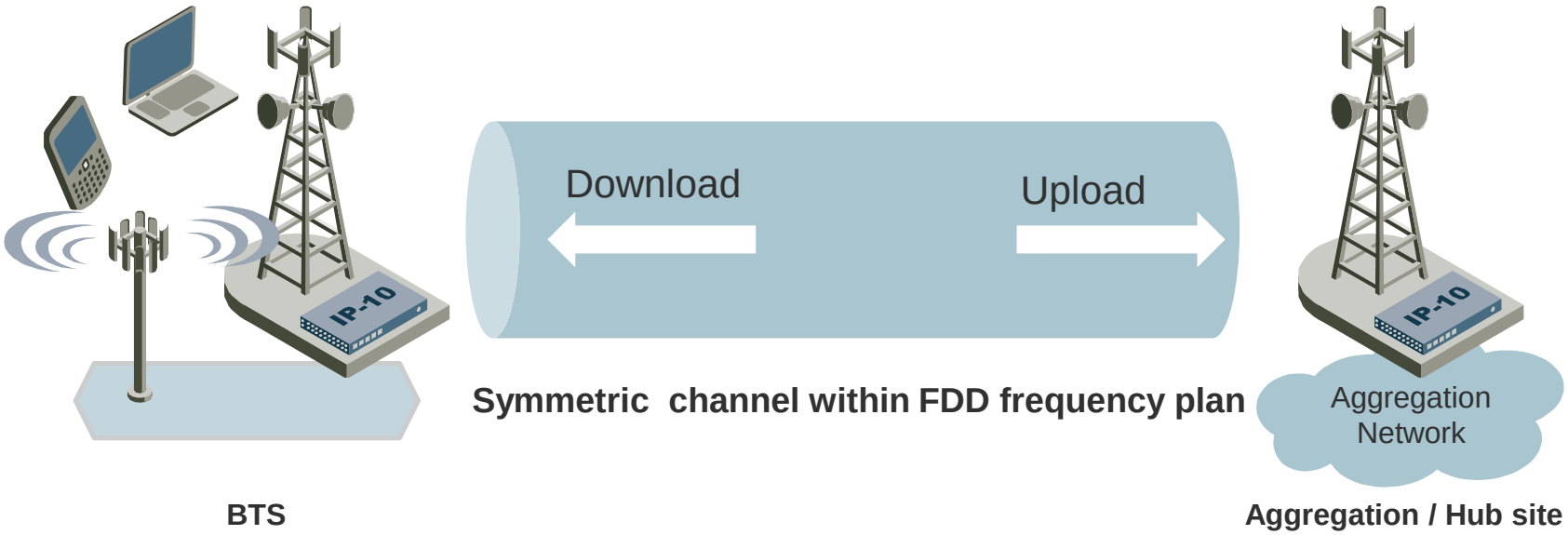
Asymmetric Bandwidth Capability

- **Voice communications is symmetric in nature**
- **3G/LTE Traffic is Asymmetrical**



Symmetric channel within FDD frequency plan

BTS

Aggregation / Hub site

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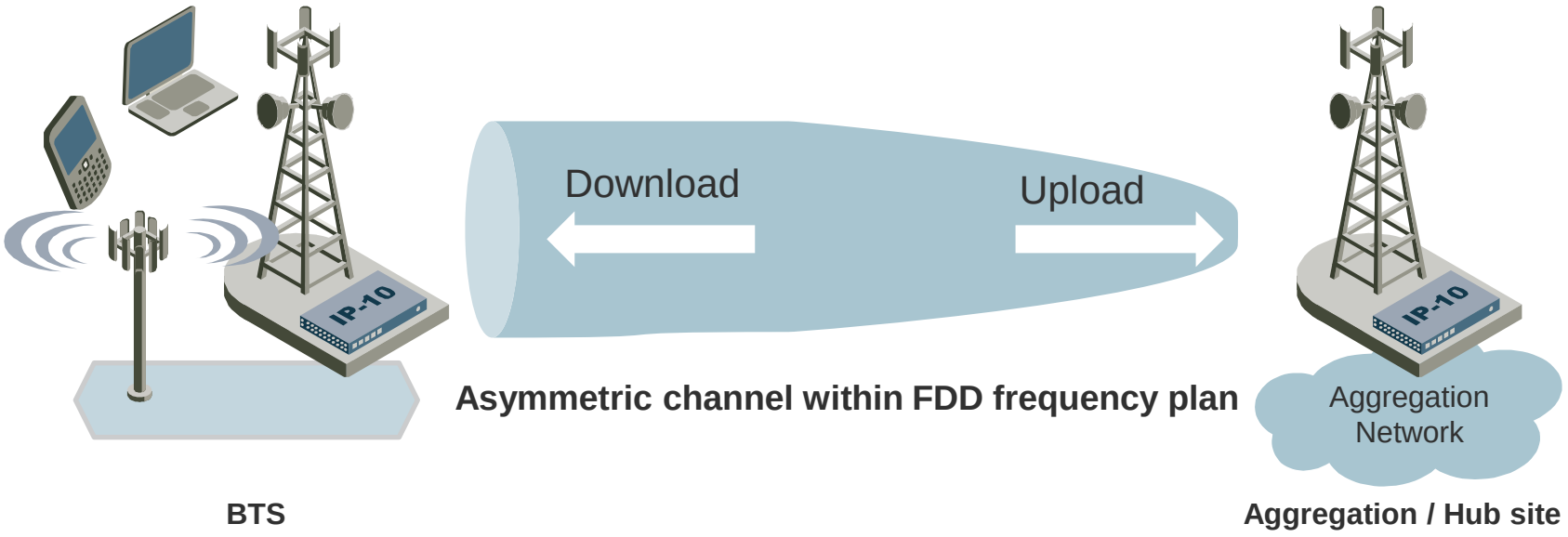
Asymmetric Bandwidth Capability

- **Allocate more capacity to downlink traffic**
- **Within an existing Point-to-Point FDD frequency planning environment**



Asymmetric channel within FDD frequency plan

BTS

Aggregation / Hub site

50% More Downlink Capacity - at no extra cost!

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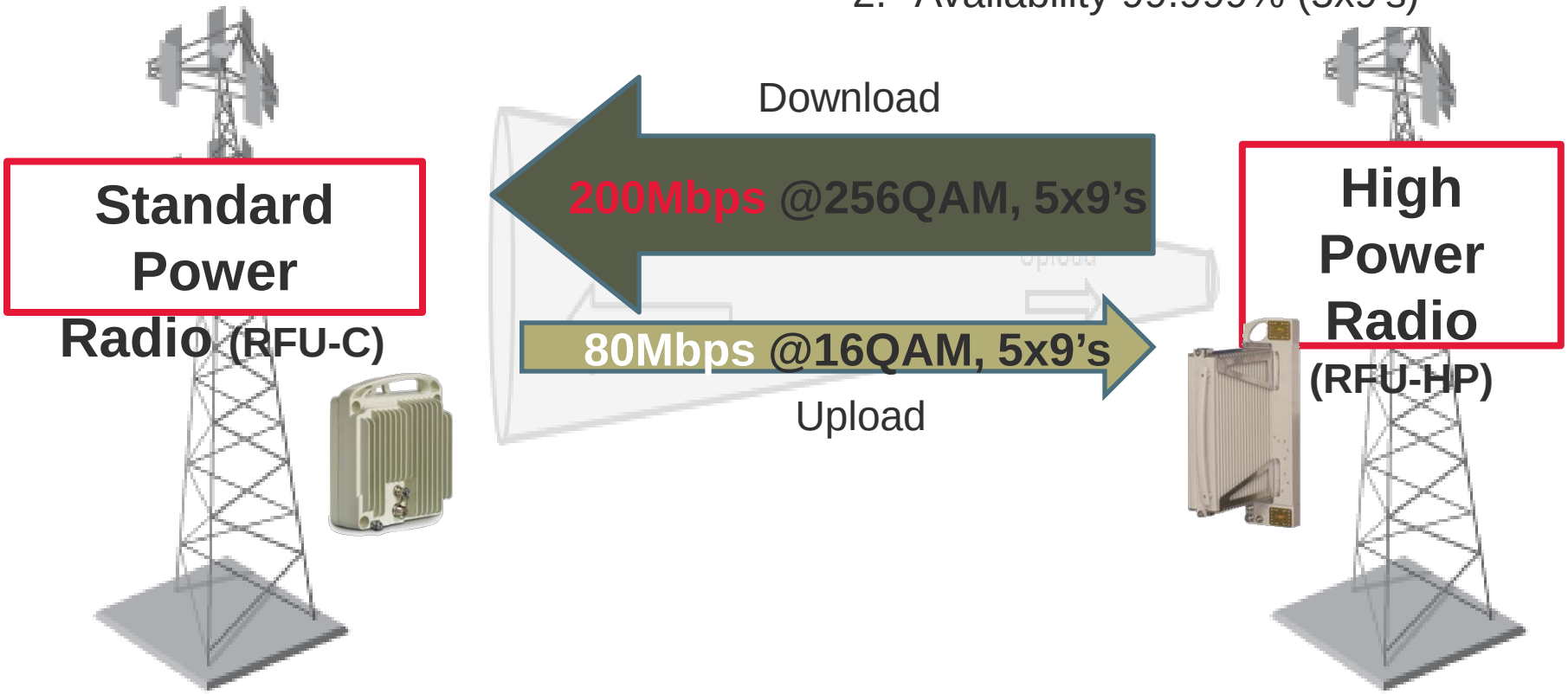
First Approach:
Asymmetrical Bandwidth – Asymmetrical Power

Wireless Link Requirements:

1. Upload 200Mbps / Download 80Mbps
2. Availability 99.999% (5x9's)



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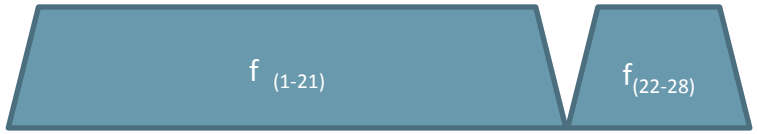
Second Approach:
Dynamic Spectrum Management
Use higher channel granularity – new paradigm

Instead of 40MHz

Use either 2x20MHz

Or 4x10MHz



Or even 30/10MHz

f (11-20) Notation refers to the channel respective slice

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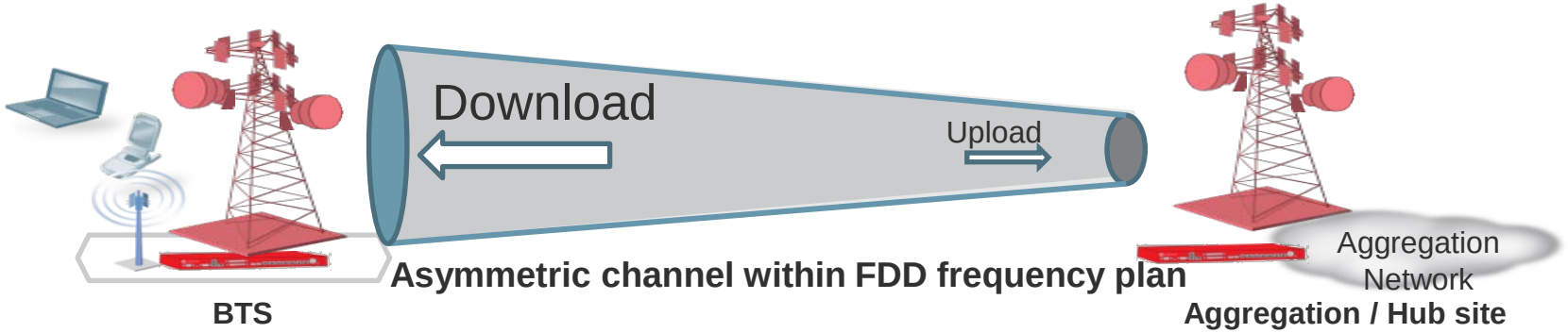
Benefits of Asymmetrical Links

- **Benefits of Asymmetrical Bandwidths vary based on use of shared frequency bands or auctioned frequency bands**

- **Shared bands such as 6, 11, 18, and 23 GHz are experiencing spectrum shortages. Assignment of asymmetrical bandwidths utilize only the spectrum necessary to transport traffic**

- **Auctioned spectrum such as 24, 28, and 38 GHz have block channel assignments resulting in limited channel pairs. Assignment of asymmetrical bandwidths creates more opportunity for channelization schemes, making more efficient use of spectrum holdings**



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Asymmetrical Links using the Shared Bands

(7) 10 MHz bandwidth channels:

Transmit (receive) (MHz)	Receive (transmit) (MHz)
5945.20	6197.24
5974.85	6226.89
6004.50	6256.54
6034.15	6286.19
6063.80	6315.84
6093.45	6345.49
6123.10 [1]	[1] 6375.14
6152.75 [1]	[1] 6404.79

(8) 30 MHz bandwidth channels:

Transmit (receive) (MHz)	Receive (transmit) (MHz)
5945.20	6197.24
5974.85	6226.89
6004.50	6256.54
6034.15	6286.19
6063.80	6315.84
6093.45	6345.49
6123.10 [1]	[1] 6375.14
6152.75 [1]	[1] 6404.79

- Creating Asymmetrical Links is possible by using paired frequencies from the 10 and 30 MHz channel plans

- All the 30 MHz channel pairs also appear in the 10 MHz channel plan

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Asymmetrical Links using the Shared Bands

- **Asymmetrical links may be achieved in the L6, 11, and 18 GHz bands through the pairing of a 30 and 10 MHz channel resulting in a 3:1 downstream to upstream ratio**

- **Asymmetrical links may be achieved in the 11 GHz band through the pairing of a 40 and 10 MHz channel resulting in a 4:1 downstream to upstream ratio**

- **Asymmetrical links may be achieved in the 18 GHz band through the pairing of a 50 and 10 MHz channel resulting in a 5:1 downstream to upstream ratio, and pairing of a 50 and 30 MHz channel resulting in a 5:3 downstream to upstream ratio**

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Asymmetrical Links using the Auctioned Spectrum

- **Holders of licenses in the 24 GHz band are granted blocks of spectrum on a geographical basis**
- **The 24 GHz band is divided into five go/return blocks that have 40 MHz bandwidths**
- **License holders may subdivide or channelize a 40 MHz block as desired**

24,250–24,290	25,050–25,090
24,290–24,330	25,090–25,130
24,330–24,370	25,130–25,170
24,370–24,410	25,170–25,210
24,410–24,450	25,210–25,250

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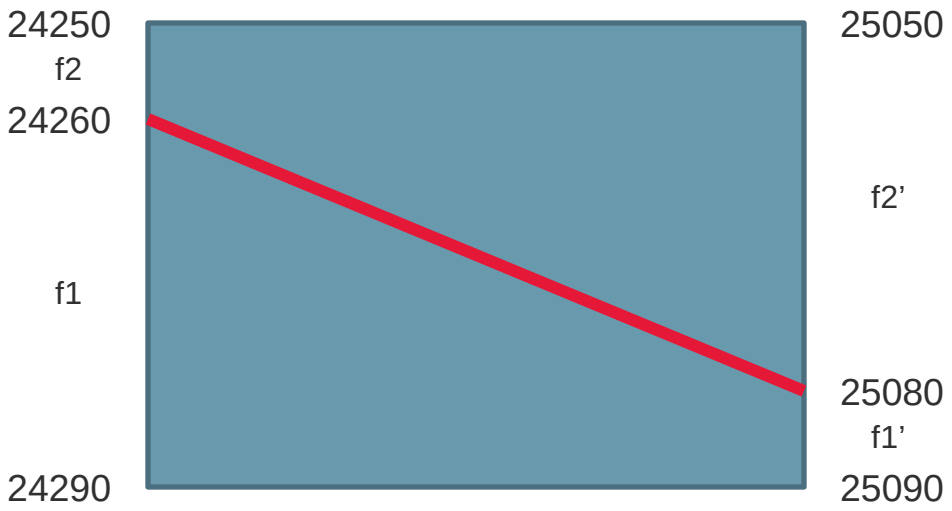
Asymmetrical Links using the Auctioned Spectrum

- **Possible division of a single 40 MHz channel block to create two asymmetrical channel pairs of 30 MHz and 10 MHz**

- **Traffic throughput is maximized downstream while spectrum is conserved in the upstream direction. The asymmetry is consistent with the nature of 3G/4G data traffic.**



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Asymmetrical Links using the Auctioned Spectrum

- **The 38 GHz band is comprised of 14 channel blocks of 50 MHz each**
- **Asymmetrical bandwidths may be created and tailored to meet the traffic demands of the 3G/4G network.**
- **Downstream to upstream ratios of 4:1, 3:2 are possible with 40 and 10 MHz channels or 30 and 20 MHz channels.**

Channel Group A		Channel Group B	
Channel No.	Frequence band limits (MHz)	Channel No.	Frequency band limits (MHz)
1–A	38,600–38,650	1–B	39,300–39,350
2–A	38,650–38,700	2–B	39,350–39,400
3–A	38,700–38,750	3–B	39,400–39,450
4–A	38,750–38,800	4–B	39,450–39,500
5–A	38,800–38,850	5–B	39,500–39,550
6–A	38,850–38,900	6–B	39,550–39,600
7–A	38,900–38,950	7–B	39,600–39,650
8–A	38,950–39,000	8–B	39,650–39,700
9–A	39,000–39,050	9–B	39,700–39,750
10–A	39,050–39,100	10–B	39,750–39,800
11–A	39,100–39,150	11–B	39,800–39,850
12–A	39,150–39,200	12–B	39,850–39,900
13–A	39,200–39,250	13–B	39,900–39,950
14–A	39,250–39,300	14–B	39,950–40,000

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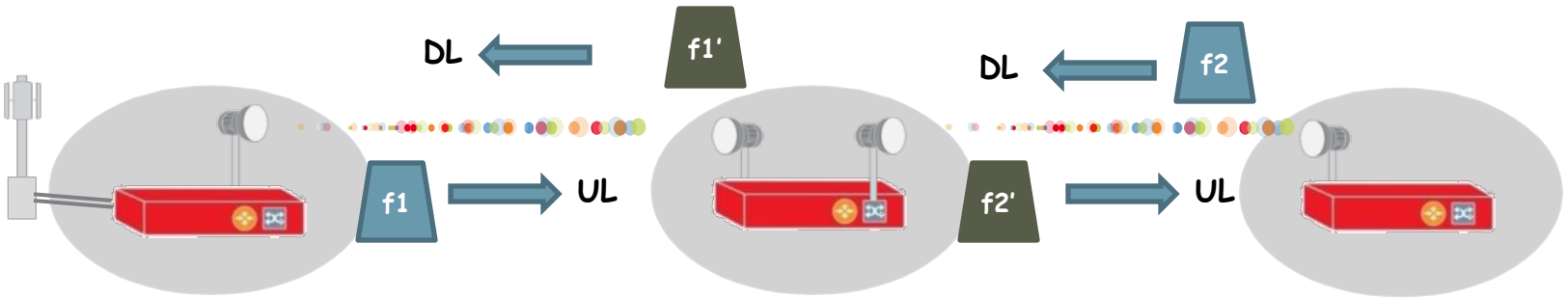
The symmetrical scenario:

A radio Chain with a single 40MHz Channel split into 2x20MHz



High channel

Low channel

- **Each link can use 2x20MHz channels.**
- **One for UL and the second for the downlink**
- **For simplicity reason, we would treat each 20 MHz as 2x10 MHz**

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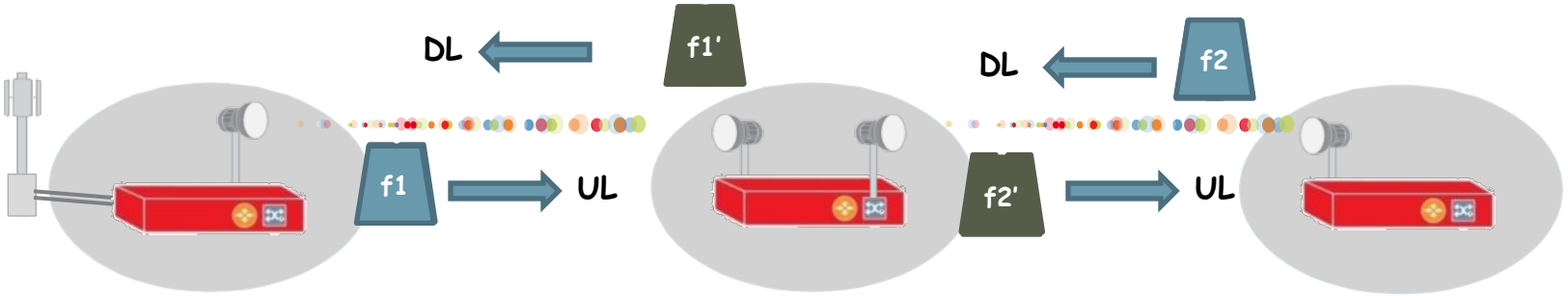
The asymmetrical scenario (Auctioned Bands)

A single 40MHz Channel split into 30MHz and 10MHz channels



High channel

Low channel

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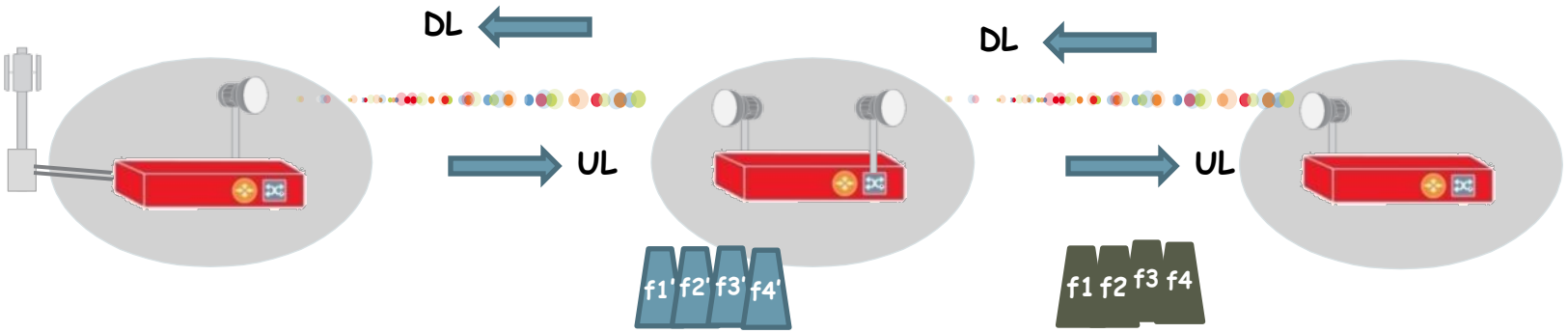

f2' High channel

f1 Low channel

- **To avoid interferences, and to use standard radios the system dynamically uses channels from the adjacent link**
- **30MHz channel for DL and 10MHz for UL are a better fit for broadband traffic**

50% more capacity for download

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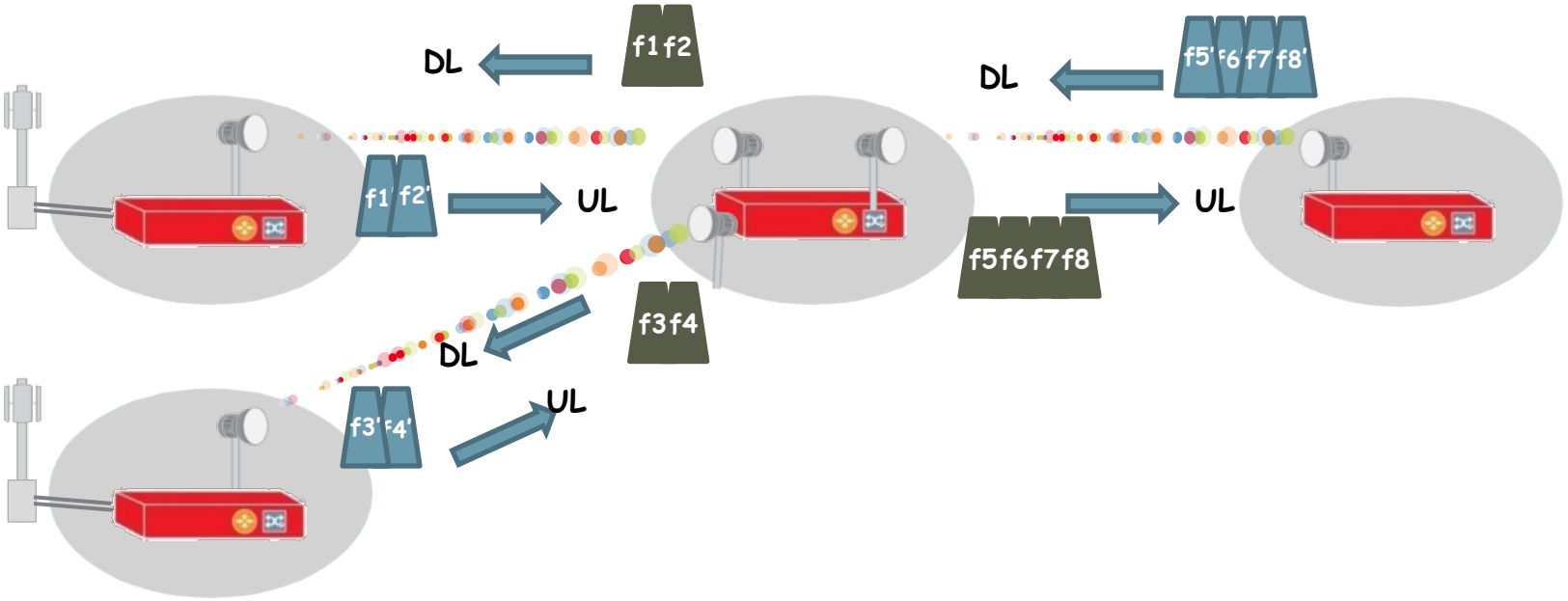
Example 2 – Aggregation (Auctioned Bands)

- **Aggregation of two 20MHz tails and one 40MHz feed (Overall we use 80MHz)**



- **In regular planning we get 350Mbps at the feed and ~170Mbps for each tail (network traffic model 2)**

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Example 2 – Aggregation (Auctioned Bands)

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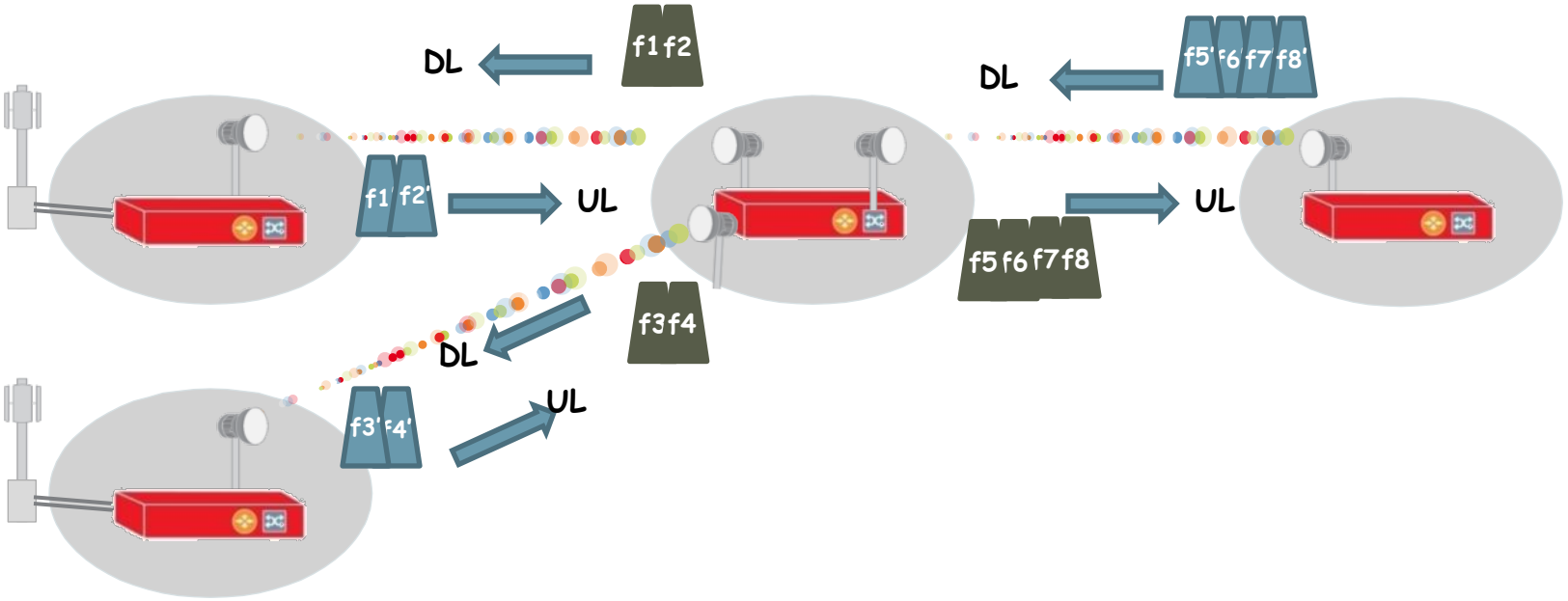

- **In regular planning we get 350Mbps at the feed and ~170Mbps for each tail (network traffic model 2)**

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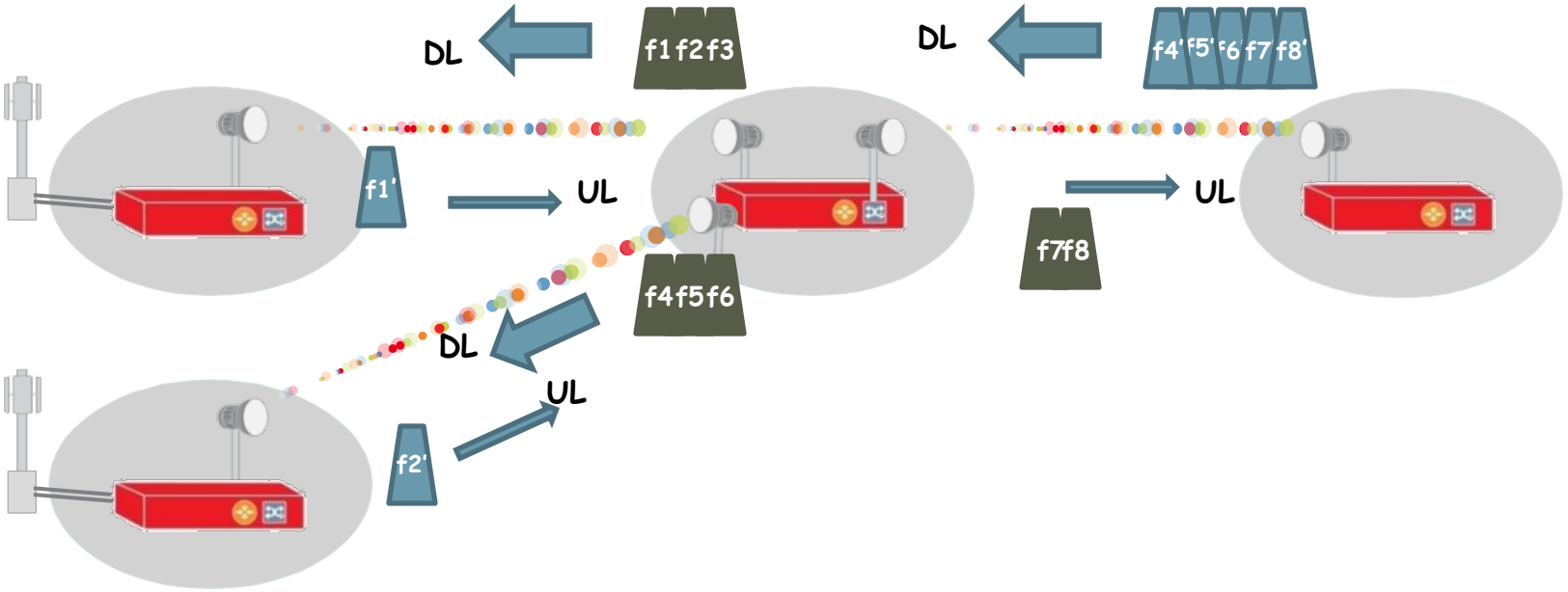
Example 2 – Aggregation – cont.

- We will split all the channels into segments of 10MHz, and assign them differently



- We now have 465Mbps at the feed using 50MHz channel for the DL and 20MHz for the UL, and 270Mbps at the tails using 30MHz channels for the DL and 10MHz for the UL (network traffic model 2)
- Overall we use the same spectrum (80MHz) and get 40% more capacity

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Major takeaways

- LTE backhaul calls for a higher spectrum efficiency
- Need to promote spectrum preservation
- Higher capacity requires efficiency at all levels

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Thank You