University of Surrey
5G Innovation Centre

This time it's different: assessing the business case for 5G

Invited seminar

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Previous cellular generations have been associated with capacity enhancement in data services

2G > 3G

- Delivering the ‘mobile internet’
- New, usable data services
- Expected large increases in revenue
- High spectrum auction costs drove up debt ratios and forced many to focus on cost management for some years
- Competition limited revenue growth
- Development of OTT players

3G >4G

- Improved data speeds and user experiences
- Limited revenue growth
- Some cost efficiency benefits
- Ongoing traffic growth presenting challenges
- Shift of balance to data services
- OTT services continue to develop

5G technologies may not meet traffic demand

- PHY (SISO) approaching Shannon limit; perhaps another +20-30% on Bits/s/Hz*
- MU-MIMO promising, but channel estimation becomes an overhead in closed loop; perhaps another +70-80% on Bits/s/Hz*
- mmW, maybe, crowd cover e.g. sports stadiums
- Het nets, no real efficiency gain, but commercially interesting
- SDN/NFV (RAN), network slicing: potential cost efficiency and agility gains
- M2M, high volume, new revenue stream for CSPs

Physical layer 1	MIMO antennas	Millimetric frequency bands	Heterogeneous networks and sharing	Machine to machine (M2M) communications	SDN/NFV & network slicing
Spectral efficiency improved: Technology improvements at the radio physical level +20-30% (OFDMA, 256-QAM, 8 x 8 MIMO) Technology improvements in the antenna system +70-80% (32Tx x 2Rx MU FD-MIMO) Potential to raise revenues from new services (e.g. high capacity)		Use of high frequency bands (e.g. c. 30 GHz) for communications Access to high bandwidth / lower cost spectrum No spectral efficiency gain	Integration of multiple networking technologies, plus asset and spectrum sharing Shared spectrum & interworking Potential to raise revenues in indoor / dense urban increased for cellular operators	Also referred to as internet of things (IoT); technology enabling direct communications between machine entities System designed for low capacity dense coverage Potential to raise revenues from new services (M2M)	Use of commodity hardware platforms Dynamic network configuration + c. 20%-30% cost advantage Time to revenue enhanced from months to weeks or days

Net spectral efficiency gain (base case LTE-A = 1.0): ~ x 2.0 – 2.4* ?

5G spectral efficiency ~ 66 Bps/Hz ?

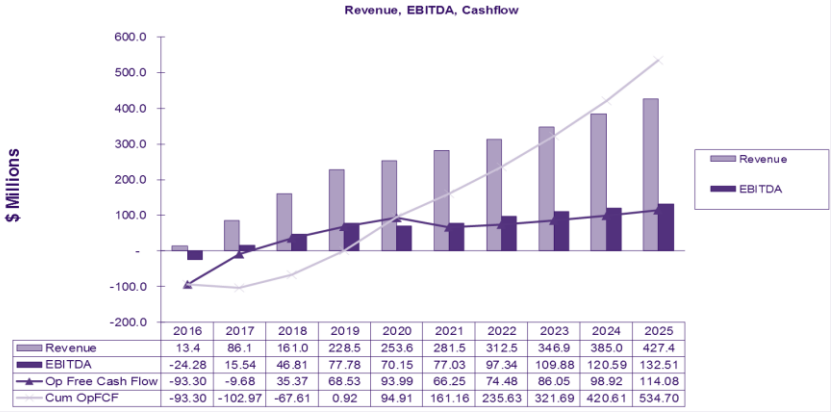
* Based on Plum Consulting dialogue at 5GIC, King's College London, plus refs:

Ji, H. et al. 'Overview of Full-Dimension MIMO in LTE-Advanced Pro'. Cornell University Library. Submitted December 2015.
'LTE Advanced Pro'. Nokia Networks white paper. Nokia Corporation. 2015.

‘Traditional’ investment theses run into trouble with 5G dimensions

- Assumptions:
  - Revenue growth (steady state, data) c. 11% CAGR
  - Spectral efficiency gain 5G:3G ~ x 23
  - Traffic growth CAGR: +50% YoY
  - Limited availability of new cellular spectrum

Proven 3G case (Greenfield, Qatar)

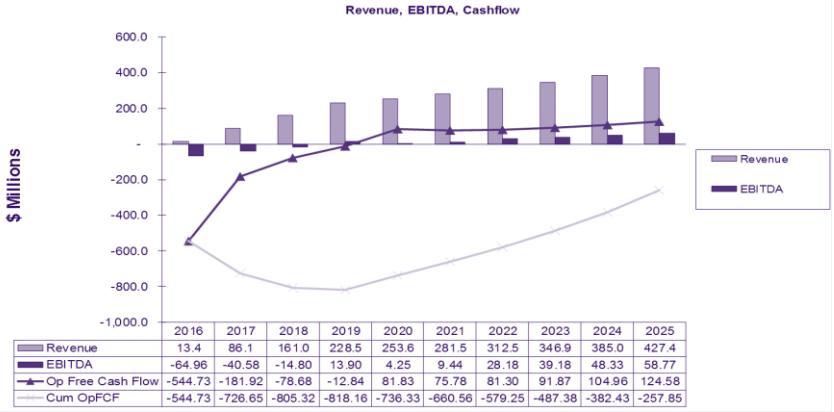


	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Revenue	13.4	86.1	161.0	228.5	253.6	281.5	312.5	346.9	385.0	427.4
EBITDA	-24.28	15.54	46.81	77.78	70.15	77.03	97.34	109.88	120.59	132.51
Op Free Cash Flow	-93.30	-9.68	35.37	68.53	93.99	66.25	74.48	86.05	98.92	114.08
Cum OpFCF	-93.30	-102.97	-67.61	0.92	94.91	161.16	235.63	321.69	420.61	534.70

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
EBITDA margin	-181%	18%	29%	34%	28%	27%	31%	32%	31%	31%
Capex/Sales	520%	30%	9%	4%	3%	7%	6%	5%	5%	4%
Revenue growth		541%	87%	42%	11%	11%	11%	11%	11%	11%

Illustrative 5G case (without 5G fabric)

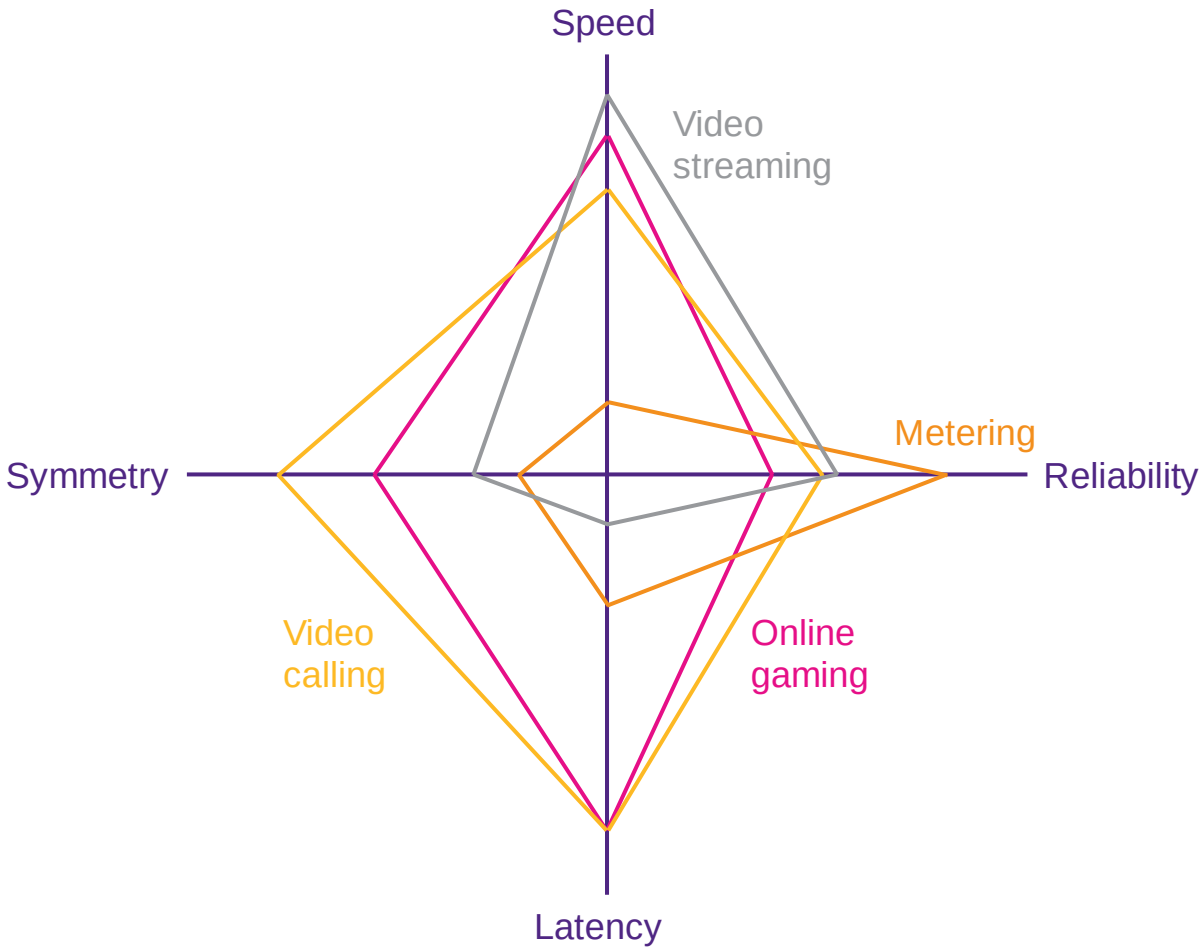
‘Traditional’ business case is *uncertain*



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Revenue	13.4	86.1	161.0	228.5	253.6	281.5	312.5	346.9	385.0	427.4
EBITDA	-64.96	-40.58	-14.80	13.90	4.25	9.44	28.18	39.18	48.33	58.77
Op Free Cash Flow	-544.73	-181.92	-78.68	-12.84	81.83	75.78	81.30	91.87	104.96	124.58
Cum OpFCF	-544.73	-726.65	-805.32	-818.16	-736.33	-660.56	-579.25	-487.38	-382.43	-257.85

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
EBITDA margin	-484%	-47%	-9%	6%	2%	3%	9%	11%	13%	14%
Capex/Sales	3535%	155%	43%	9%	8%	10%	9%	8%	7%	7%
Revenue growth		541%	87%	42%	11%	11%	11%	11%	11%	11%

We can look at a wider portfolio of services, which requires a wider set of bearer services:



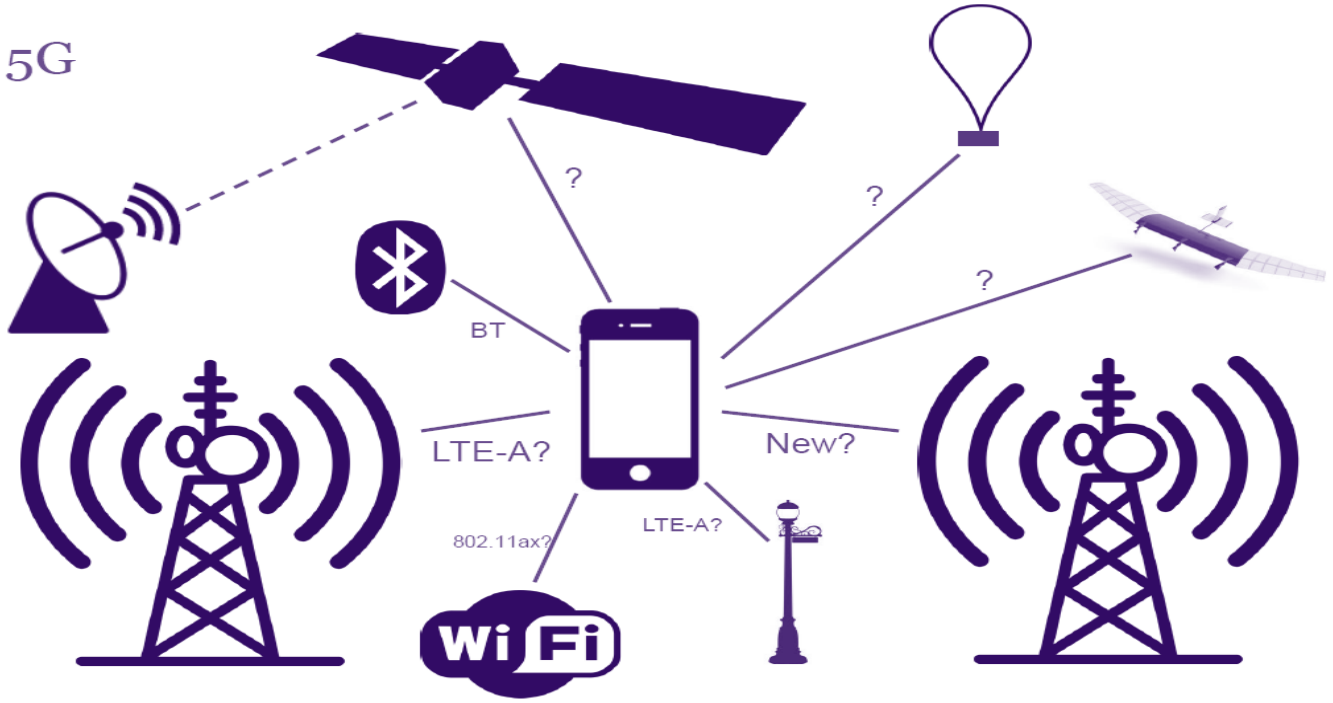
We can enhance the value proposition for cellular:

- 5G is:
  - 'Never having to think about my network connection'
  - 'I don't care if you don't offer radio here, I want access now'
    - Enough capacity (average aggregate throughput)
    - Enough speed (peak data rate)
    - Ubiquitous coverage
    - Fast access
    - Seamless usage
    - Network roaming
    - Heterogeneous networks

Note:
3G 'case' was about:
'anything, anywhere, anytime'

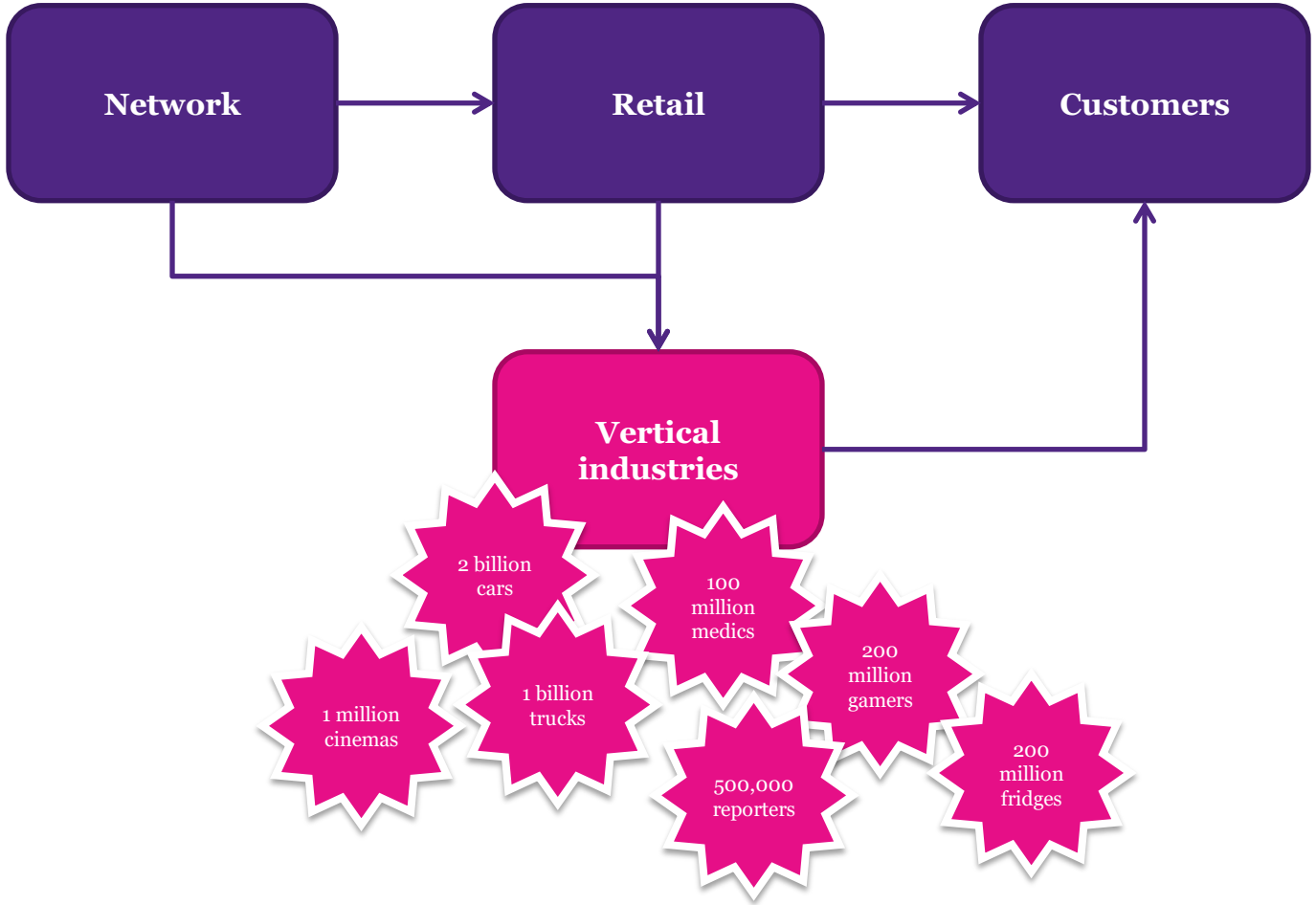
No, customers don't care about the technology, but they do care about the service and the price – which depends on the commercials *and* the technology

At the radio end, 4.5/5G is evolving as a ‘fabric’ of connected systems



Source: ‘Fuelling the 5G future: understanding and delivering the spectrum requirements’, Plum Consulting, 2nd Asia-Pacific Spectrum Management Conference Bangkok, April 2016.

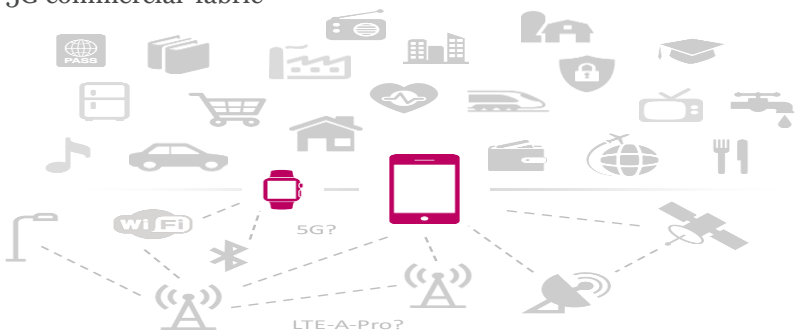
At the business level, to offer rich new revenue streams, 5G needs to evolve as a commercial 'fabric'

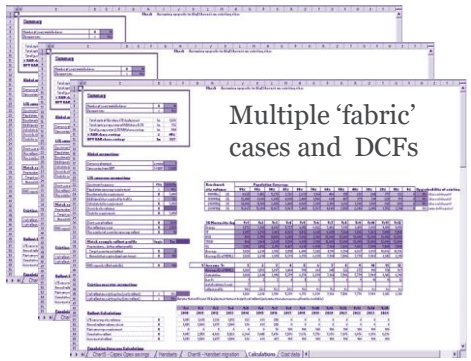


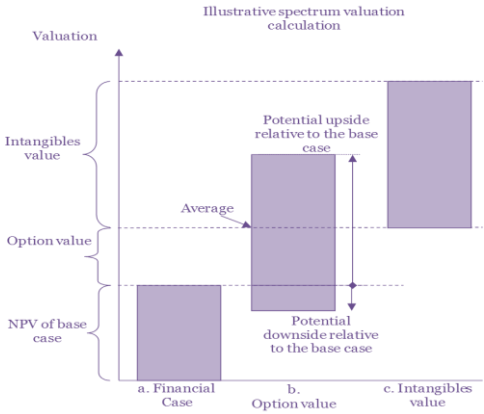
Spectrum management will be challenging

- Traffic growth: carrier aggregation to 100MHz isn't going to work, at least on competitive grounds
- Operation across multiple networks, technologies and bands (e.g. 700 MHz, 3.4 – 3.8 GHz, mmW) adds complexity
- Sharing and pooling in spectrum (e.g. LSA, LAA, LWA, MOCN, fluidity) will be attractive to manage costs and improve efficiencies, much as it has been in network infrastructure
- Economic valuation of spectrum will be more challenging with uncertainty in cash flows, higher complexity in the commercial value system, and a higher level of intangibles

5G commercial 'fabric'







Plum framework for spectrum valuations towards 5G: