RTT TECHNOLOGY TOPIC
November 2016

Smart Antennas
5G Beam forming – power control and handover

A recent research paper from Ericsson referenced user specific beam forming as a 'smart antenna' enabling technology for 5G in the centimetre and millimetre band.
https://www.ericsson.com/research-blog/5g/massive-beamforming-in-5g-radio-access/

The objective is to deliver isotropic gain (range gain) but also to provide the basis for interference mitigation and capacity gain.

'Smart antennas' have been promoted as a mechanism for delivering coverage and capacity gain for the best part of 25 years. Early pioneers such as Arraycomm in the US (founded in 1992) struggled to gain traction in the operator community.
http://www.arraycomm.com/products/a-mas-software/

Attempts by Nortel to introduce products for the 1800 MHz and 1900 MHz bands also met with limited success.
http://www.rfsworld.com/nortel-and-rfs-collaborate-to-deliver-multi-beam-pcs-smart-antenna-technology,62,1,pressreleases,283.html

Partly this was due to the additional site cost incurred from the additional size of antenna arrays and the extra wind loading for sub 2 GHz antennas. In practice, most cell sites settled on three, six or nine sector arrays with limited adaptive capability provided by remotely managed mechanical or electrical down tilt.

Smart antennas can be defined as antennas that adaptively change beam pattern to mitigate interference, provide additional directional capacity or realize directional gain. The adaptation can either be realized by processing in the analogue domain or digital domain or a hybrid mix of both. The trade-off is between A to D power consumption (the 'cost' of digital processing) and inter element signal interference (the 'cost' of analogue processing). Hybrid schemes use interleaving and inter sub array coding to manage this interference.

Smart antennas need to be closely integrated with CQI based power control and handover algorithms and scheduling algorithms. If these are poorly executed, the result will be additional signalling load. This reduces capacity and the overall power available for user data throughput. Power control and handover decisions made on the basis of channel measurement and reporting introduce hysteresis. This increases physical layer latency. Power drain in user and IOT devices will also increase.

LTE Release 9 (for TDD) and Release 10 (for FDD) introduced standards for adaptive beam forming including associated signalling requirements but being included in the standards process does not equate to widespread deployment and in practice most power control and handover algorithms remain optimised for cell to cell or channel to channel handover rather than beam to beam handover.

One option for 5G is to integrate beam forming with handover algorithms based on the observed or calculated position, direction of travel, speed and prior behaviour of the user device or mobile IOT device. In this month's technology topic we review the progress being made with this approach in Wi-Fi networks and study the beam forming control options for wide area mobile broadband.

Read on

The starting assumption should probably be that 2G, 3G, 4G and 5G macro and micro and pico sites will be deployed differently but will have some commonalities. So for example it is likely that an existing site will have a mix of sub 1GHz, L band and S band sectored antennas, possibly some C band in some markets and a mix of centimetre and millimetre band fixed point to point back haul.

Micro and Pico sites could also potentially support 2.4 and 5 GHz Wi-Fi and possibly 60 GHz Wi-Fi. Macro sites may also have television at the top of the mast.

To this already complex mix of antennas, feeders and RF power amplifiers we are now expected to add dual band centimetre/millimetre band 5G with adaptive antenna arrays covering 28 GHz, 38 GHz and 72 to 77 GHz and 82-87 GHz. There could also be upwards facing dish antennas connecting with Ku and Ka-band satellites.

The fixed point to point backhaul antennas and 5G antennas could be supported from common RF hardware so that bit might be relatively simple. The problems start when you consider how to manage beam forming, beam to beam handover and inter and intra system handover which could include 5G to Wi-Fi handover and/or 5G to satellite handover.

It is hard to avoid the conclusion that driving this process from CQI measurements would be impossibly complex. This suggests a need to consider location based and direction of travel based handover algorithms as an alternative.

Cellular networks have always more or less known where their subscribers are at any moment, where they are going and how fast they are going but the resolution and accuracy of the process has continuously improved.

The transition from Cell ID positioning and timing based positioning in GSM to the use of the synchronisation sequences in W-CDMA to the use of dedicated positioning reference signals in 4G (observed time difference of arrival with a positioning reference signal) has improved positioning and location accuracy from hundreds to tens of metres.

Open sky GPS provides one metre accuracy and 5G could equal or improve on this with the modest caveat that relative timing errors would need to be closely controlled - one nanosecond of time uncertainty is equivalent to one third of a metre of location and positioning ambiguity.

IEEE 802.15.3 provides a contemporary example of location aware joint scheduling and power control and low signalling overhead node selection and could potentially provide the basis for highly predictive power control and handover algorithms based on position and location, direction and speed of travel.

Users and IOT devices including mobile IOT devices have repetitive short term and long term behaviour both in terms of their mobility and bandwidth requirements.

This can be characterized in terms of predictability and rate of change – for example

Static - are devices that never move and are therefore 100% predictable in terms of their location

Nomadic devices move but only connect when they are stationary

Mobile **–** mobiles are mobile though at times can be static or nomadic.

Mobiles can be sub divided into ***habitual*** where position and usage are highly predictive and ***erratic.*** Erratic will be the hardest to predict though it would be rare for there to be a complete absence of repetitive behaviour. Most of us have highly predictive weekly and daily behaviour patterns which can be expressed in terms of location, direction and speed of travel all of which correlate closely with our connectivity requirements.

Static, Nomadic and Mobile – location, direction of travel and repetitive behaviour as the basis for predicting connectivity requirements

100%	***Predictability***		***0 %***
Static	***Nomadic***	***Mobile***	
		Habitual	***Erratic***

By comparison, signal strength and interference based handover algorithms (algorithms based on channel quality indication/CQI measurements) are not inherently predictive and have intrinsic hysteresis which will be problematic for adaptive beam control.

Adaptive beam forming in user devices and IOT devices

It is also theoretically possible to achieve directional gain in user devices and IOT devices particularly at Ka-Band (28GHz and 38 GHz) and V and W band (70 and 80 GHz).

However body shielding and hand capacitance effects will be problematic in user devices and power drain will be problematic in IOT devices. There will however be opportunities to develop innovative smart antenna enabled relays and repeaters which could potentially deliver cost effective hot spots for rural coverage.

Summary

The 5G physical layer will need to use narrow beam (fractional beam width) antennas to deliver isotropic gain to offset propagation losses in the centimetre and millimetre band. These beam patterns could continuously track individual users/devices or users/devices could be switched from beam to beam or supported on multiple beams.

In previous technology topics we have described this as *'**progressive point to point**'* in which a user/device is being serviced at any particular moment from a line of sight link (or links) which will be continuously changing.

While fully adaptive beams might be theoretically more efficient it may be harder to manage inter system and intra system interference so multiple fixed switched beams might be a pragmatically better option.

Either approach would require handover and power control algorithms that are as yet untried and untested. If these algorithms were based on CQI measurement then disproportionate signalling load, hysteresis and physical layer latency will be incurred. The power drain in the user device will also be insupportable.

Positioning, location and direction and speed of travel and other network resident context based prediction methods are therefore likely to be more efficient both for 5G beam to beam handover and inter and intra system handover and could be part of a dedicated standalone 5G control plane.

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A timely and critical investigation into 5G and satellite industry supply chain economics and spectral and space asset value

Telecommunications is a trillion-dollar industry with 5G promoted as the next big enabler of growth both in developed and developing economies**.** However, this growth will only be achieved if the satellite industry is motivated to share its spectral and space assets including C band and Ku and Ka- band spectrum.

Mobile and satellite operators are highly leveraged and are reliant on vendor supply-chain support. "Over-the-top players," such as Google and Facebook, are starting to invest in access infrastructure and are cash rich. Additionally, the military and the automotive industry are increasingly important stakeholders.

So, the question is: Who will own added value in next- generation mobile broadband?

This study is being developed as a syndicated research opportunity in association with Collaborata

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The satellite industry is engaged in a transformation of its Ka-band spectral and space assets. Ka-band spectral assets, particularly the 28 GHz and 38 GHz bands, are emerging as the sweet spot for 5G terrestrial network deployment with AT&T and Echostar and Verizon and Viasat as examples of potential 5G technical and commercial partnerships.

'A timely and critical investigation into 5G and satellite industry supply chain economics and spectral and space asset value' analyses the implications of the growing inter dependency of these two industries and will make extensive use of presentation graphics to highlight present value and risk distribution in the industry with modelling of three future industry scenarios assigning different weightings on terrestrial and satellite spectral and network value and the relative market reach value and technology value of each supply chain and the major players in each supply chain. The value modelling will use inputs from industry interviews correlated with our own research and in house data sets and the in house research and data bases of our project partners, Policy Tracker and The Mobile World.

This is a unique opportunity to join us in a syndicated research project in which costs are shared between two or more sponsoring agencies providing the opportunity to precisely dimension the technical and commercial risks and opportunities of Ka-band spectral asset and space asset and terrestrial asset integration.

Follow this link for more details
http://www.collaborata.com/projects/186

5G BOOK – 5G Spectrum and Standards – Geoff Varrall
Published by Artech House

The spectrum, band plan and standards choices for 5G radio systems and the relative technology and economic impact of these choices on the industry supply chain, operator community and end users.

£117.00 available to pre-order at a discounted price of £87.00
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