RTT TECHNOLOGY TOPIC
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Dormancy, Density, Devices

Our November 2016 Technology Topic reviewed the RF energy efficiency gains achievable from optimized 5G beam forming and power control and handover techniques.

However significant performance improvements are being achieved in present mobile networks including legacy GSM by implementing advanced dormancy (extended discontinuous reception - eDRX) which substantially reduces power drain in IOT devices.

These techniques are coupled with an assumption that the link budgets for IOT will need to be improved by an order of 15 to 20 dB over present voice and data networks in order to deliver adequate indoor and outdoor coverage.

Link budget increases are also needed to support emerging vertical market requirements such as safety critical automotive and energy grid applications. This implies that energy efficiency is not just an IOT requirement but an essential pre condition for all devices and networks.

The interrelationship between link budget and device and network power efficiency is complex and counter intuitive.

An improved bi directional link budget will mean that data can be sent in shorter bursts. If this is coupled with effective dormancy algorithms then a net reduction in IOT device power drain should be achieved. Dormancy algorithms may however introduce unacceptable latency and delay variability.

Extended discontinuous transmission is also not compatible with the power control and handover algorithms needed to support power efficient mobile devices. If IOT link budget gain is achieved through higher network density then the additional signalling load will increase network power consumption for mobile devices (small cells consume three times more power than macrocells).

In this month's technology topic, we argue that the only way to square this particular circle is to implement optimized dormancy techniques for stationary IOT devices with mobile devices better served by implementing handover coupled to position, direction and speed of travel and historical use and performance patterns.

The general industry assumption that network density is the only way to deliver reduced path loss is also debatable. An increase in flux density may in many instances be more economic for wide area mobile broadband devices.

Last but not least we highlight the continuing problem with RF efficiency in multi band multi RAT mobile devices and the related impact on network and device efficiency and network economics.

Read on

Dormancy algorithms in IOT devices – extended discontinuous receive (eDRX)

Dormancy algorithms are already widely used in user devices to reduce energy use by powering down processor logic. The need to reduce power drain in IOT devices has however prompted a broader look at power saving modes on the radio interface. Specifically in 3GPP Release 12, LTE

Cat 0 IOT devices are allowed to decide how often they need to be active in order to transmit and receive data.

In the lowest power saving mode, the device does not look for paging or any other network signalling, the network is not allowed to page the device and is required to hold any data that arrives until a designated wake up moment.

The time between wake up moments can be up to 12.1 days though something closer to two minutes is more common. The standard discontinuous receive cycle is 2.56 seconds.

Link budget improvements for IOT including EC- GSM

The link budget improvements in LTE for IOT machine to machine applications are delivered by reducing channel bandwidth and are claimed to yield a 155 dB path loss compared to 147 dB for LTE VoLTE and 137 dB for LTE high speed data.

Source Nokia http://resources.alcatel-lucent.com/asset/200175

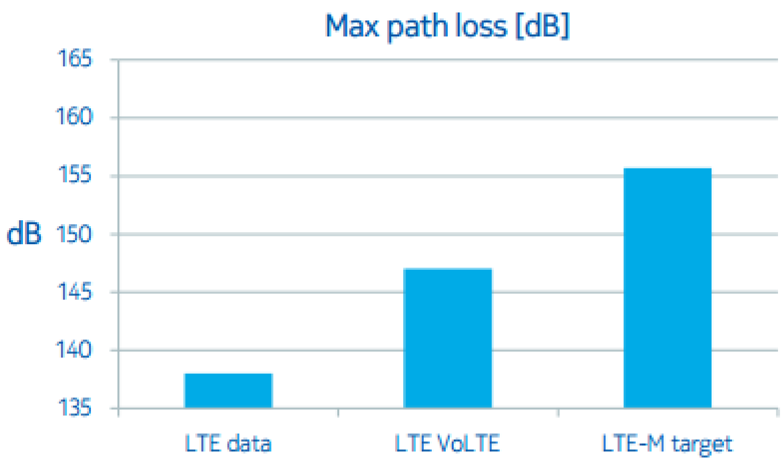

Figure 3. Maximum path loss with LTE M2M

3GPP Release 13 takes a different approach with an enhanced coverage variant of GSM (EC-GSM) which uses additional channel coding (signal repetition) and signal combining to achieve a claimed 20 dB improvement over 900 MHz GPRS.

However these techniques are not efficient or effective for higher data rate exchanges or for applications where devices are mobile. Higher data rates need wider channels to maintain multiplexing efficiency, increasing coding overhead improves the link budget but reduces net throughput and extended discontinuous receive cycles are incompatible with handover and power control algorithms.

LTE handovers are either backward or forward. In a backward handover, the network performs cell switching and notifies the mobile terminal of the destination cell. In a forward handover, the mobile terminal performs autonomous switching to pick up the destination cell. The basis of the decision in either case is available channel quality (CQI - Channel Quality Indication).

In our November 2016 technology topic (5G Beam forming- power control and handover) we suggested that these present handover algorithms are inefficient when applied to Inter RAT handovers particularly as the choice of network and band plan broadens.

Consider for example the signalling and decision overhead implicit when the possible handover options include GSM, EC-GSM, GPRS, WCDMA, 4G LTE, centimetre and millimetre band 5G, tri band Wi-Fi and sub space or satellite spanning frequency bands from 450 MHz to 71 GHz (the upper end of the new UMFU unlicensed allocation in the US). Determining handover on the basis of CQI measurements across this combination of networks and bands and channels would be absurdly inefficient.

Our suggested alternative was to couple handover decisions to the observed or calculated position of the user or IOT device, direction of travel, speed and prior usage and service patterns.

Assuming mobile devices are GPS enabled this allows the device to decide on best connect options in real time not on the basis of channel knowledge but on the basis of known local availability of base stations and access points and their past rating in terms of performance, effectively context driven cognitive radio.

Best connect could be on the basis of lowest energy drain, highest throughput (sometimes though not always the same option) and lowest delivery cost.

The advantage would be that device/user added value would be directly coupled to network performance and efficiency.

Device performance and future technology options

However there remains the massive caveat of device performance. As frequency bands are added into small form factor devices, as channels and pass bands get wider and as new technologies are supported it can be generally stated that multiplexing efficiency should increase. However it can also be generally stated that RF efficiency reduces.

On the receive path this is a consequence of additional filters and switch paths, compromised antennas and poor noise matching and the higher noise floor implicit in wider channels and pass bands. Front end compression from unwanted signal energy will also be more problematic and will require wider front end dynamic range (requiring more power).

On the transmit path, higher order modulation with large peak to average power ratios requires additional digital processing to maintain power added efficiency. The additional digital signal processing can project additional noise into the receive path.

Large amounts of envelope variation may require maximum power relaxation of the order of several dB with a negative impact on uplink range and throughput. Poor power matching on the transmit path introduces issues of heat rise and reflected power.

Poorly matched broadband antennas with ineffective ground planes can result in a negative gain of 6 or 7 dB. It is also harder to establish an adequate compromise between power matching (RF transmitter power efficiency) and noise matching (downlink receive sensitivity).

Together these effects can result in a loss of at least 10 dB which directly subtracts from the supportable path loss. MIMO performance can also be highly variable both between devices and across supported bands.

It also highlights the inadvisability of decommissioning GSM channels or compromising GSM performance in user/IOT devices, not uncommon when signal paths are optimized for LTE rather than legacy GSM.

Finally it should not be assumed that 5G band plans should be TDD. In particular it is important to note that TDD does not scale efficiently to the larger cell radius cells that will be needed to make 5G commercially viable.

From the network side, TDD introduces significant additional time interference issues and requires base stations to be co sited.

In terms of device performance, TDD devices will be vulnerable to receiver desensitisation and device to device interference particularly in the centimetre and millimetre bands where filter Q will be inherently lower than existing sub 3 GHz RF front ends.

On the receive path, a combination of compromised receive sensitivity and reduced selectivity will directly impact downlink data throughput, data reach and data capacity. On the transmit path, maximum power relaxation and compromised power matching will directly impact uplink data throughput, data reach and capacity.

Device RF front end performance should be the start point of any spectrum allocation and band plan discussion but is generally the last thing to be considered.

Summary

Effective mechanisms exist for reducing the power drain of stationary IOT devices based on extended dormancy algorithms.

These are however incompatible with present handover and power control protocols for mobile devices.

Present handover and power control protocols are becoming progressively less efficient as band and technology options increase over time and there are increasingly persuasive arguments for favouring forward handovers in which the device takes access decisions based on position, direction of travel, speed of travel, knowledge of the local position of base stations and access points, user and device requirement and usage and performance history rather than CQI based decisions which are becoming increasing unscalable.

The traditional view has always been that handover in small cells will generally be determined by congestion. In larger cells, handover will generally be determined by signal quality but in 5G there will be the additional requirement to manage beam to beam handover and beam steering. Beam to beam handover is almost certainly a candidate for direction of travel based decision making. Beam steering may require a more hybrid approach with signal quality remaining as an input. Irrespective of the method used, careful integration with scheduling algorithms will be a necessity.

Irrespective of the access algorithms used, it is bordering on the insane to throw away 10 dB of link budget due to compromised RF front end design in user and IOT devices. Better specified active and passive components are a partial solution but introduce additional cost. A more profound architectural solution is still the Holy Grail for many RF design teams but like the Holy Grail remains elusive.

Minimizing noise and achieving efficient gain and sufficient dynamic range in low cost centimetre and millimetre band RF front ends can probably only be achieved through fundamental materials innovation to which presently there is limited visibility.

It is also looks unwise to decommission GSM for the foreseeable future and compromising GSM performance in user devices is better avoided.

Network density is not necessarily the only or best way to reduce path loss. Avoiding maximum power relaxation in user devices on the TX path, improved sensitivity on the receive path and uplink and downlink antenna gain from tower mounted base station sites – flux density rather than network density, will often be a more economic option.

For local area coverage it is hard to see how 4G or 5G can compete economically with ultra-dense Wi-Fi particularly if the rest of the world follows the US initiative to extend unlicensed spectrum at 60 GHz from 57 GHz to 71 GHz - nearly 15 GHz of contiguous bandwidth.

This implies that the sweet spot for 2G, 4G and 5G will be wide area rather than local area with high data rate and mobility as key requirements and implies a need to ensure perceived IOT requirements do not compromise the performance economics of wide area mobile broadband and legacy networks and devices.

Dormancy works for stationary IOT but less well in wide area mobile.

Flux density is more economic than network density.

Network delivery economics are substantially influenced by device performance.

Dormancy, density and devices together have a critical impact on IOT and mobile broadband spectral value.

Device performance and device economics in particular should be the start point for all band plan discussions.

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