RTT TECHNOLOGY TOPIC
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3 G Network Density

The relationship between link budgets and network density in a voice centric network is now reasonably well understood. Generally it can be said that every dB of link budget translates into a 10% increase (or decrease) in network density. A vendor who can genuinely deliver 2 – 3 dB of link budget gain over and above a competitor can potentially deliver substantial fiscal advantage in terms of both capital and operating outlay.

There are counter arguments, of course. The performance limitations of cellular networks are often determined by interference rather than noise, in which case selectivity is more important than sensitivity but generally, the 1 dB/10% rule holds . . . for voice.

For multi-media, the inter-relationship between link budget, network density and 'end user experience' is less clear cut.

Let us start with the business model of the typical operator presently contemplating a 3G network investment.

The assumption is that a premium tariff structure can be built on a quality of service proposition – that a user will pay more for a 100 m/s end to end service than a (variable) 100 ~ 500 m/s service.

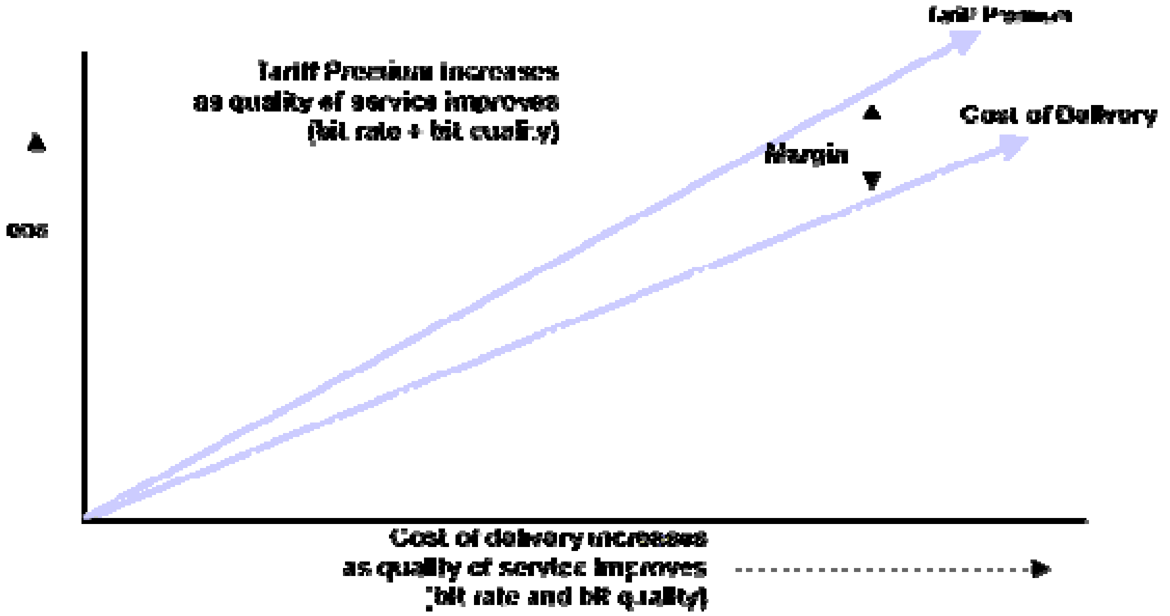


FIG 1

The snag is that the cost of delivery increases as the quality of service improves. In the figure, we show the tariff premium increasing faster than the cost floor – this will not necessarily always be the norm!

Delivery cost increases as quality of service improves because the channel and the traffic on the channel has to be managed and delivered in a more deterministic (ie time controlled) manner.

Standard IP (Internet Protocol) over a channel which at some point in its end to end journey is band limited, struggles to meet precisely pre-defined quality of service criteria.

Traffic management session oriented protocols such as multi-protocol label switching, diffserve and RSVP address this problem by establishing virtual circuit switched paths through the packet switched network. In doing this, these protocols absorb bandwidth, degrade other users QOS and decrease channel utilisation.

If you make IP as deterministic as physical circuit switching the bandwidth utilisation is the same! The cost of delivering delay sensitive traffic increases as the delay sensitivity increases. This is true for wireline and wireless access networks.

For wireless, however, we have an additional issue to address – the quality and variability of the radio channel.

Most 3G cellular networks are being planned on the basis of delivering user information at bit error rates of between 1 in 10^3 and 1 in 10^6 at information rates of between 16 kbps and 2 Mbps.

User Bit Error Rates – Performance Expectations

- **Mobile**
  1×10^{-3} to 1×10^{-6}
  1 bit error per 1000 1 bit error per 100,000

  At sensitivity threshold, eg –102 dBm
  1×10^{-3}
  2 bit errors per 1000

- **Fixed Access 1st Generation (eg Nortel Proximity)**
  1×10^{-6}
  1 bit error per 1,000,000 (ITU-T BER objective for 64 kbps end to end transmission)

- **Fixed Access Second Generation (eg Airspan)**
  1×10^{-7}
  1 bit error per 10,000,000

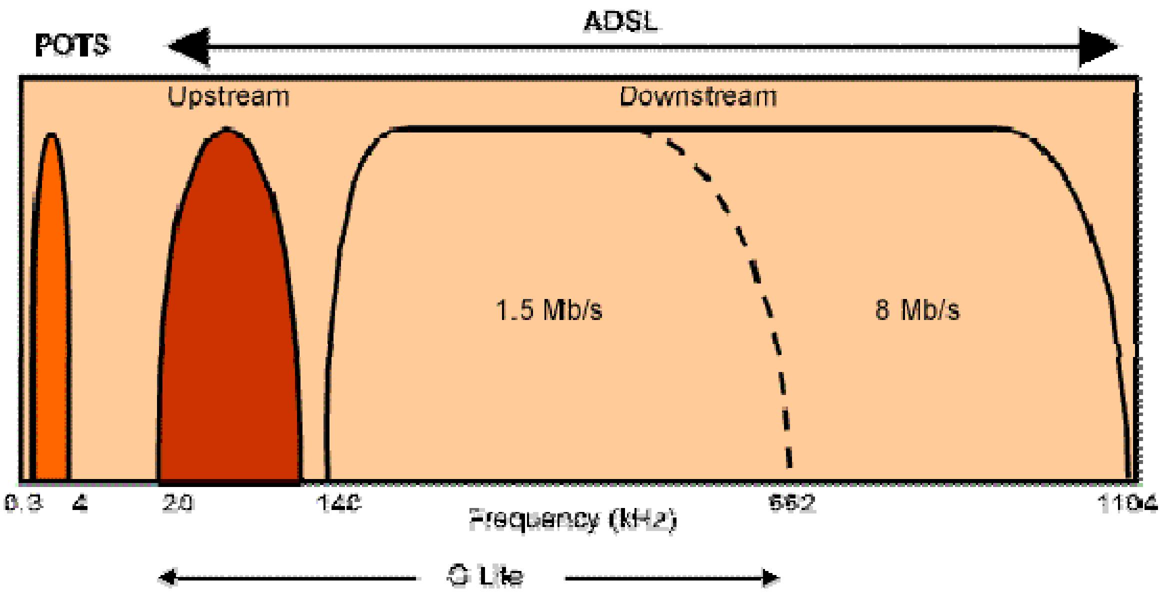
- **Fixed Access third Generation (eg Teledesic)**
  1×10^{-10}
  1 bit error per 10,000,000,000

On the wireline access side, two important trends need to be considered. Firstly, at the application layer, we are seeing a magnitude increase in compression ratio every 5 years. As of today, it is not unusual to see image and video streaming compression ratios of 70 to 1 in proprietary implementations. In 5 years, this is likely to be closer to 700 to 1. This content will be undeliverable over a 1 in 10^6 radio channel. Note also, that although the error rate could be reduced by error coding (send again protocols), this in turn would produce unacceptable, unsupportable variable delay.

Over the same 5 years (1999 – 2004), we will see the increasingly widespread adoption of ADSL on copper access networks.

ADSL delivers 8 M/bits downstream and 640 kbps upstream on a standard twisted pair. It does however need filters to be added to prevent interference to and from legacy POTS appliances. G-Lite will probably be more common in that it is in effect a form of splitterless ADSL, i.e. you don't need a home or office visit from a telco techno before you turn the thing on. The 'cost' is a relatively modest 1.5 M/bs downstream and 512 k/bits upstream, not very different from 3G wireless **but it will deliver this at a 1 in 10^{10} bit error rate (one bit error per 10 billion bits)**.

Note that in effect, ADSL and G-Lite are translating the benefits of frequency planning and frequency re-use (previously the advantage of wireless) to the wireline copper access side.



If the 3G business model is based on the notion that radio access should provide an equivalent 'wireless user experience' to that enjoyed by a user connected to a wireline termination then a 1 in 10^{10} bit error rate has to be the wireless access benchmark and that benchmark in itself will not stand still – fibre can deliver 1 in 10^{12} – a virtually errorless channel.

Which brings us back to the issue of network density. Assuming the same latency performance, moving from 1 in 10^3 to 1 in 10^6 bit error rate requires an additional 3 dB of link budget gain, moving from 1 in 10^6 to 1 in 10^9 needs an extra 3 dB, moving from 1 in 10^9 to 1 in 10^{12} needs an extra 3 dB (double the power, double the power, double the power).

The challenge for third generation cellular is therefore going to be how to deliver a physical layer which can transparently service an application layer optimised for wireline access. In an ideal world, the user should experience little or no difference between a wireline and wireless accessed application. A winning market proposition cannot be built on an apology.

The wireline user experience will be determined by the performance over time of wireline copper access pair gain products presently being brought to market – ADSL, G-Lite, HDSL. The wireless user experience will be determined by the performance over time of the link gain products presently being brought to market as part of the 3G cellular proposition including 3G RF sub-systems – smart antennas, high Q filters et al.

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