RTT TECHNOLOGY TOPIC
March 2003

Turbulent networks

In 1909, A K Erlang published his 'Theory of Probabilities and Telephone Conversations' - we still use Erlangs today to dimension Node B, RNC and core network capacity and (rather dangerously) use Erlang traffic arrival formula to design network processor components.

The good thing about voice traffic is that it is reasonably predictable. Multi-media traffic is also quite predictable though we have less experience and knowledge of 'mixed' media/'rich' media traffic arrival patterns (and less experience of how we should treat the traffic).

This means that networks don't always behave as expected - their behaviour is not consistent with traditional queuing theory. The anecdotal experience is that as we move from voice to a mix of voice, data and multi-media, networks become progressively more badly behaved.

One reason for this bad behaviour is the increasing burstiness of the offered traffic which effectively puts network components (network processing and network router buffers) into compression. This results in packet loss and (if using TCP) transmission re-tries.

These 'bandwidth effects' can be due to transmission bandwidth constraints, buffer bandwidth constraints and/or signalling bandwidth constraints. Traffic shaping protocols (TCP, RSVP, MPLS etc) may help to modulate these effects or may make matters worse! It is thus quite difficult sometimes to know whether we are measuring cause or effect when we try and match traffic arrival and traffic throughput patterns.

Benoit Mandelbrot (1982) and subsequently Kihong Park, Willinger and others have characterised network traffic in terms of a series of multiplicative processes and cascades - the end result is a turbulent network.

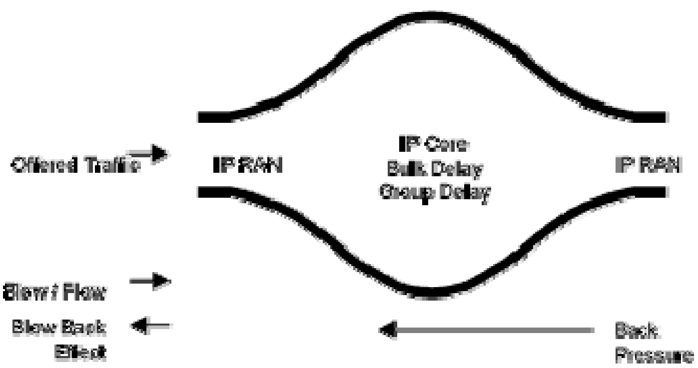

Figure 1 - The Network as a Filter (The Turbulent Network)

Whether using TCP or UDP, the network effectively behaves as a filter including bulk delay and group delay effects and creates back pressure when presented with too much traffic or bursty traffic (which puts the network into compression). The effect is similar to the reflection co-efficient in matching networks (VSWR).

The problem of turbulent networks is that it is difficult to predict the onset of turbulence - the point of instability, i.e. the point at which a 'fluid' flow becomes laminar. The reason that it is difficult to predict the on-set of turbulence is that turbulence is turbulent. Lewis Fry Richardson (the uncle of Sir Ralph Richardson) produced some seminal work on turbulence just prior to the First World War when there was a particular interest in knowing how well aeroplanes could fly! Richardson was so inspired by the mathematical complexity (and apparent unpredictability) of turbulence that he wrote a poem about 'little eddy' behaviour - the behaviour of the little eddies or whorls that you notice in dust storms or snow storms.

'Big whorls have little whorls which feed on their velocity
And little whorls have lesser whorls and so on to viscosity.'

So What Do Whorls Have to Do with Telecom Networks?

Well, in order to understand network instability, we need to understand the geometry of turbulence. At what point does the flow of a liquid or gas **or packet stream** go from smooth to laminar (an unsmooth flow) and what are the cumulative causes.

In a wireless wide area network, the root cause is the increasingly wide dynamic range of the traffic being fired **into** the network from cellular handsets. 3GPP1 specifies that data rates can vary on the uplink between 15 kbps and 960 kbps from frame to frame (10 millisecond to 10 millisecond), ie we have bursty bandwidth coming from multiple similar sources. Unfortunately merging these traffic streams together does not necessarily result in traffic smoothing - bursty data streams aggregated together may produce even burstier traffic streams. This burstiness exercises (effectively compresses) RF and DSP components in the radio layer and router and switch components in the network. RF and DSP components in compression go non-linear and create intermodulation and distortion. Router and switch components in compression produce packet loss and packet delay (first order effects) and loss and delay variability (second order effects). These effects can be particularly damaging for non-elastic/in-elastic traffic.

Kihong Park adds to the anxiety by suggesting that this offered traffic (in particular the burstiness of the offered traffic) can become strongly 'self similar'. Self-similar traffic is traffic that shows noticeable (and when scaled, remarkably similar) burst patterns at a wide range of time scales - typically four or five orders of magnitude, milliseconds, seconds, tens of seconds, hundreds of seconds, thousands of seconds.

It's rather like qualifying the effect of using multiple OVSF codes at the radio layer, we can predict the dynamic range of the burstiness but not when the burstiness will occur, through we can predict how often it will occur.

Kihong Park's work is based on multiple source variable bit rate video. The traffic coming from multimedia handsets within the next three to five years will not be dissimilar therefore we need to consider the impact of this traffic on network resource provisioning.

Self similar traffic has long range dependence - this means that it has a cumulative 'fill effect' on the buffer, ie we need more buffer bandwidth than traditional telecom traffic theory would suggest. However, if we add additional buffer bandwidth we not only increase end to end delay (first order effect) but end to end delay variability (second order effect). Given that as we shift towards a richer media multiplex, with an increasing percentage of conversational traffic exchanges our traffic by definition will become **less** elastic, this will be quite unsupportable.

So What's the Answer?

Philippe Jacquet, one of the contributors to Kihong Park's book paints a gloomy picture 'Actual router capacitors are dangerously underestimated with regard to traffic conditions'.

While this is almost certainly true it is also reasonable to say that provided transmission bandwidth is adequately provisioned then next generation networks will work quite well but will cost rather more than expected.

It also implies a significant shift away from present network processor design trends - a topic that we revisit in next month's HOT TOPIC.

References:

Self similar Network Traffic and Performance Evaluation.
Edited by Kihong Park and Walter Willinger
Wiley, New York, 2000 Edition. ISBN 0-471-31974-0

The Fractal Geometry of Nature
Benoit B Mandelbrot
1983 Edition. ISBN 0-7167-1186-9

About RTT Technology Topics

RTT Technology Topics reflect areas of research that we are presently working on.

We aim to introduce new terminology and new ideas to clarify present and future technology and business issues.

Do pass these Technology Topics on to your colleagues, encourage them to join our

Push List and respond with comments.

Contact RTT

RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

If you would like more information on this work then please contact

geoff@rttonline.com

00 44 208 744 3163