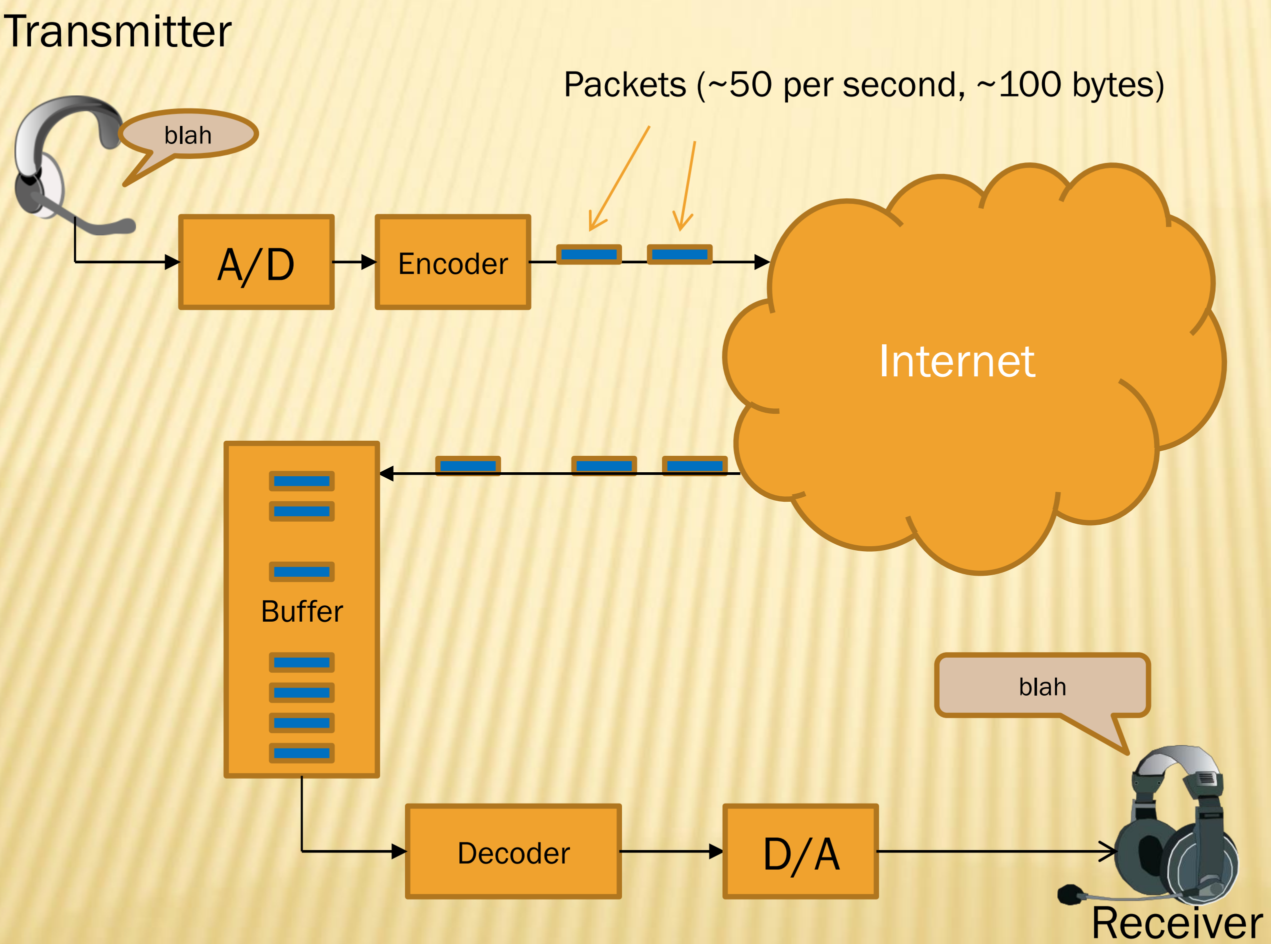
HOW SUSTAINABLE ARE VOIP AND OTHER REAL-TIME PROTOCOLS?

Ulrich Speidel, 'Etuate Cocker, Firas Ghazzi, Nevil Brownlee
Department of Computer Science, The University of Auckland

AGENDA

- VoIP
- Packet journeys
- Implications of network growth and technological progress
- Why worry?
- The beacon network
- Initial observations
- Packet train arrival quality: Jitters and entropy
- TCP trends
- Conclusions

VOICE OVER IP AND OTHER REAL-TIME PROTOCOLS



Transmitter…
- …encodes analog voice signal digitally
- …chops encoded byte stream into a packet train

Packets…
- …travel via Internet to receiver
- ….experience individual delays
- …may travel via more than one path and may get re-ordered

Receiver…
- …buffers packets to establish constant-rate data flow to decoder

Decoder and D/A…
- recover analog signal and replay it

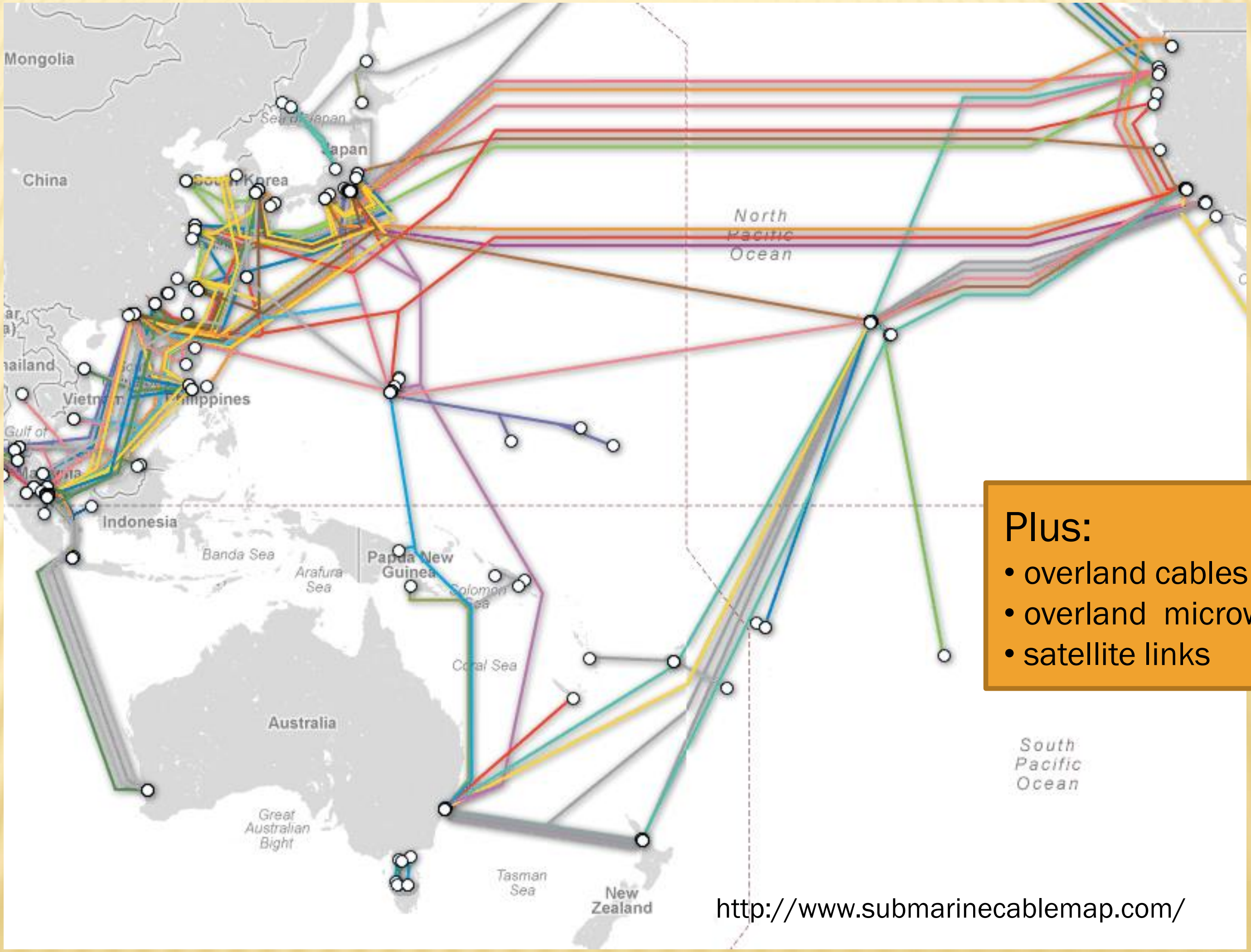
A PACKET'S JOURNEY ACROSS THE INTERNET

- Transmitted on time with sub-millisecond precision
- Stuck in queues at routers. Sometimes dropped rather rudely.
- Separated from predecessor and successor packets of the same flow at load balancing routers
- Taken for a ride: cheapest path over shortest/fastest path
- Made to wait in the receiver's buffer until the rest of the crowd turns up
- If anything goes wrong, it's nobody's fault. Everyone's put in their best effort

Etuate Cocker - ecoc005@auckland.ac.nz

PACIFIC RIM SUBMARINE CABLES

2013



Plus:

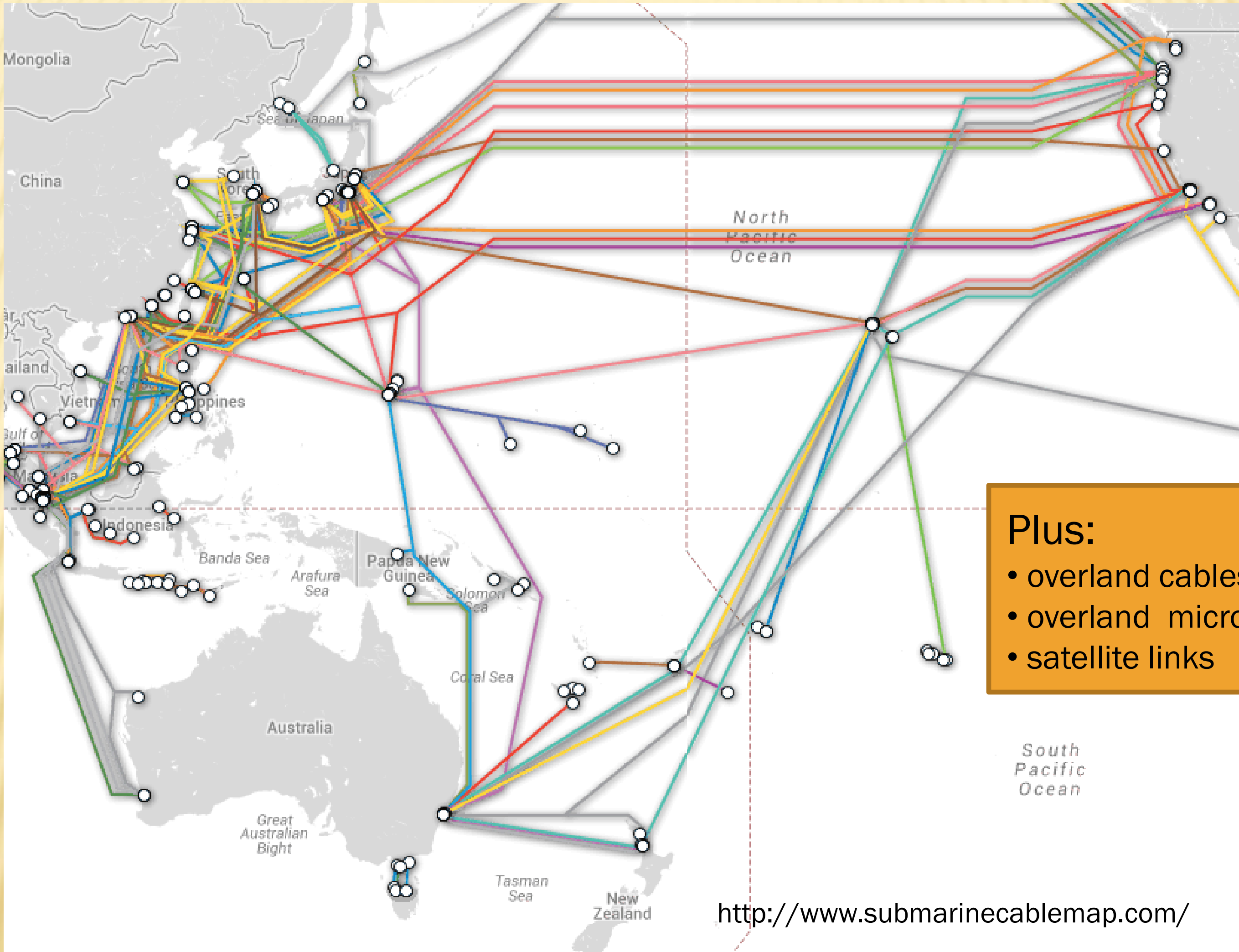
- overland cables
- overland microwave links
- satellite links

http://www.submarinecablemap.com/

Etuate Cocker - ecoc005@auckland.ac.nz

PACIFIC RIM SUBMARINE CABLES

2014



Plus:
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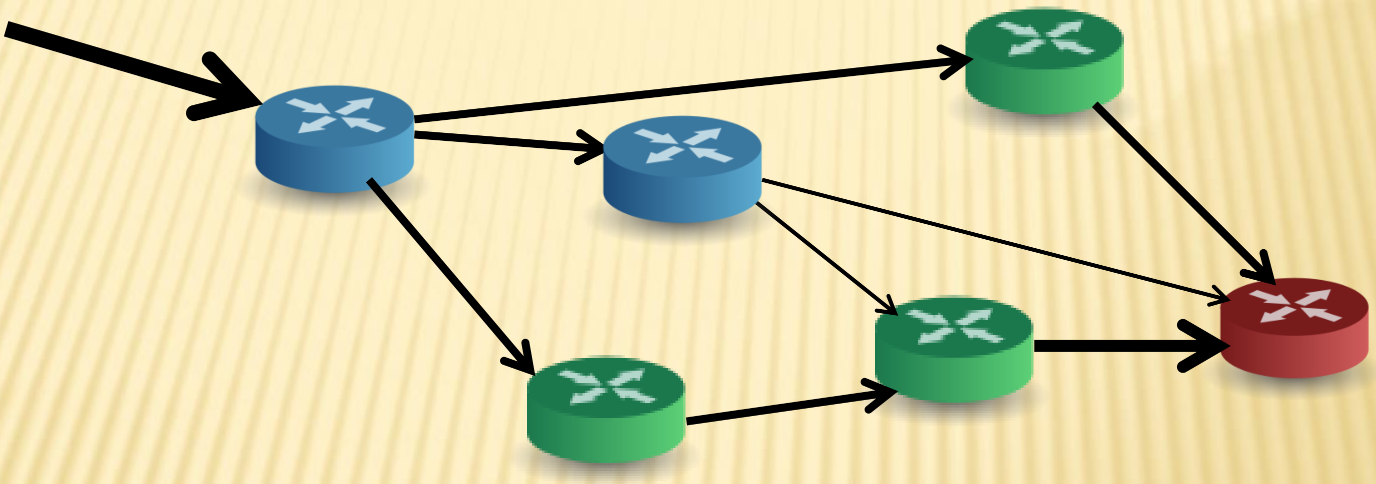
LOAD BALANCING ROUTERS

- Load balancing routers send packets to the same destination across different links



- If packets from the same stream are load balanced, it causes them to take different paths and experience different latencies
- In some cases, packets may overtake each other (out-of-order arrivals)
  - requires latency differences of ~20 ms at usual VoIP packet rates (50/s), which are (still) rare
  - likelihood increases with packet rate

PROGRESS: BLESSING OR CURSE?

- Infrastructure growth follows demand – typically 30-40% p.a. traffic growth on the Internet
- More physical links
  - In principle shorter physical paths, but…
  - more choice in upstream connectivity, so…
  - lower likelihood of shortest path being used!
  - Higher risk of zig-zag routing
  - More routers = more queues (effect potentially partially masked by tunneling)
- Higher bandwidths (WDM) and faster / routers (optical, parallel queues)
  - But: Parallel queues increase the risk of out-of-order arrivals

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WHY IS REAL-TIME TRAFFIC SUCH AS VOIP SO IMPORTANT?

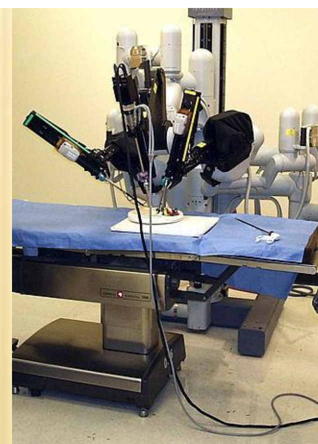
1. Contact centre industry
   - Economy of calls
   - Significant up front investment
   - NZ's hidden cottage industry


YAHOO NEWS
Search News
G'day caller: Aussie firms offshore jobs to 'little brother' NZ
REUTERS By Jackie Range and Naomi Tajitsu
September 17, 2013 4:30 PM

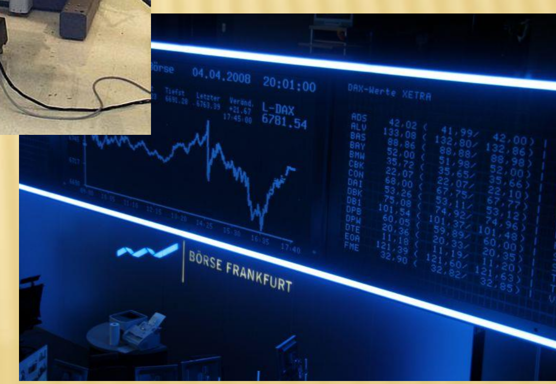

British phone answering service in Auckland grows
5:30 AM Wednesday Jul 17, 2013


Wellington.Scoop
With LINDSAY SHELTON
Art Business Education Entertainment
New Australian contact centre will offer 100 new jobs in Wellington's CBD
February 28, 2013 0 comments
Press Release – Grow Wellington
Wellington has scored an early year economic win with Contact Centres Australia (CAA) opening their first New Zealand contact centre in the CBD early in March.

2. Remote surgery and manipulation
   - Patient safety
   - Duration (cost) of operation
   - Significant up-front investment



3. Financial industry
   - Real-time trading



4. Ability to stay in touch with friends, family, colleagues, business partners over distance
   - Ability to recruit, retain, do business, and cooperate

http://en.wikipedia.org/wiki/File:Laproscopic_Surgery_Robot.jpg
http://www.flickr.com/photos/travel_aficionado/2396819536/
http://flickr.com/photos/94833286@N00/1573456981

WHAT WOULD A WORLD WITHOUT REAL-TIME INTERNET LOOK LIKE?

- E-mail, web, and downloads would still work (and become faster, probably)
- More push-to-talk like communication, not really real-time
- More voice and video messages
- Streaming audio and video would still work (with potentially significant amounts of buffering delay)
- Remote regions in Internet topology would probably drop off first. E.g., Pacific Islands, Africa, South America
- Serious digital divide between remote regions and regions closer to the core
- Not entirely a function of poverty!

INTRODUCING… IIBEX

- …the *International Internet Beacon Experiment*
- A "beacon" is an Internet-connected computer able to exchange synthesized traffic in a highly controlled manner with other beacons
- Currently: 30 beacons in Canada, Cook Islands, Fiji, Germany, Japan, Kiribati, Macau, Malaysia, New Zealand, Solomon Islands, South Africa, Switzerland, Tonga, Tuvalu, and the United States
- Further beacons are under construction
- Log data backhaul to Auckland – around half a GB per day

THE BEACON NETWORK

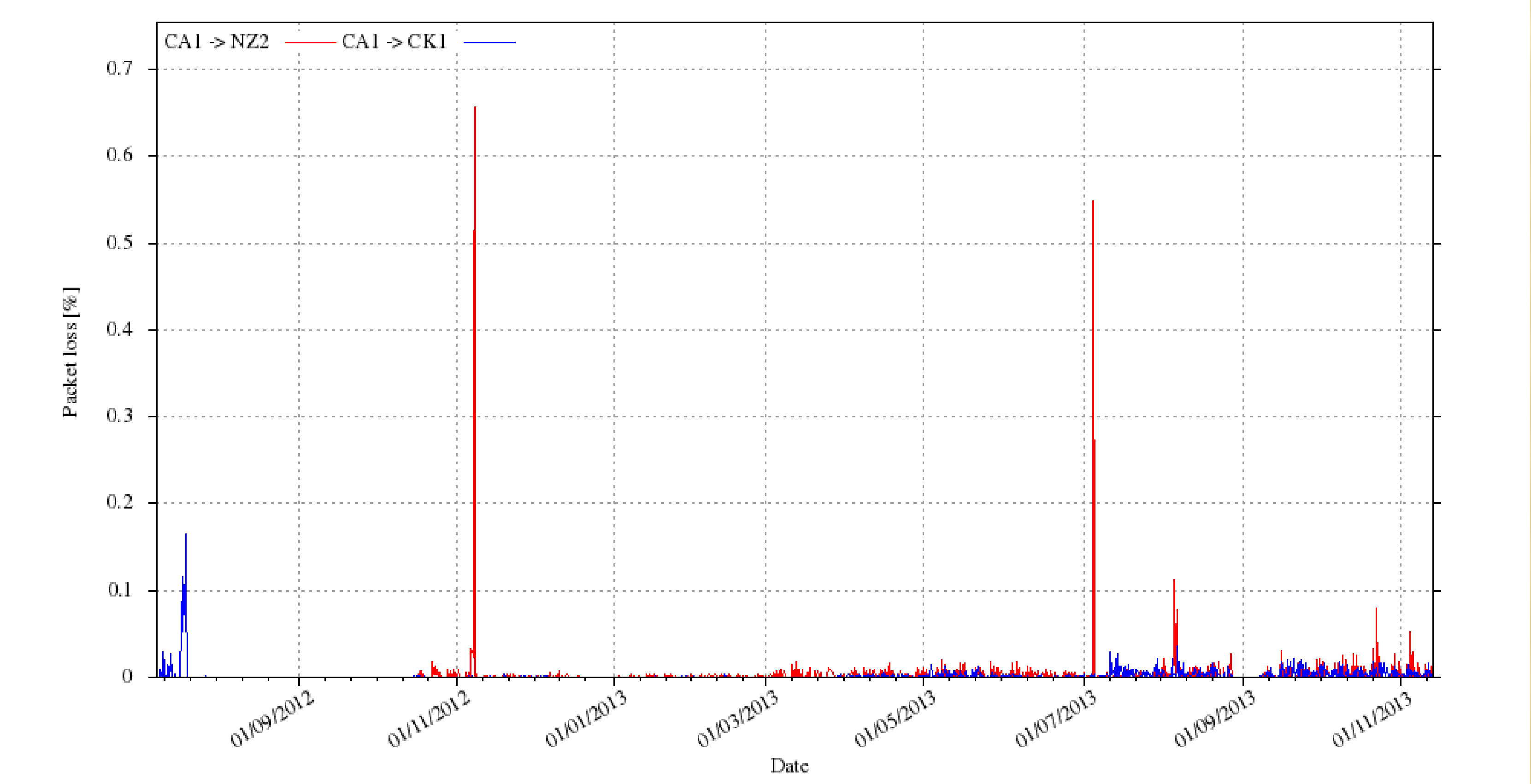
TYPICAL BEACON UDP EXPERIMENTS

- Beacon exchanges 10,000 UDP packets of 110 bytes with a partner beacon
- Packets transmitted every 20 ms
- Packets are timestamped and serial-numbered
- At receiving end, packets are logged with arrival time stamp, serial number, arrival sequence number, and TTL observed
- This experiment typically runs 3 times a day between selected beacon pairs
- Used to derive packet loss rates, out-of-order-arrivals, clock drift, jitter, arrival time entropies and (for some beacons) MOS estimates (mean opinion score)

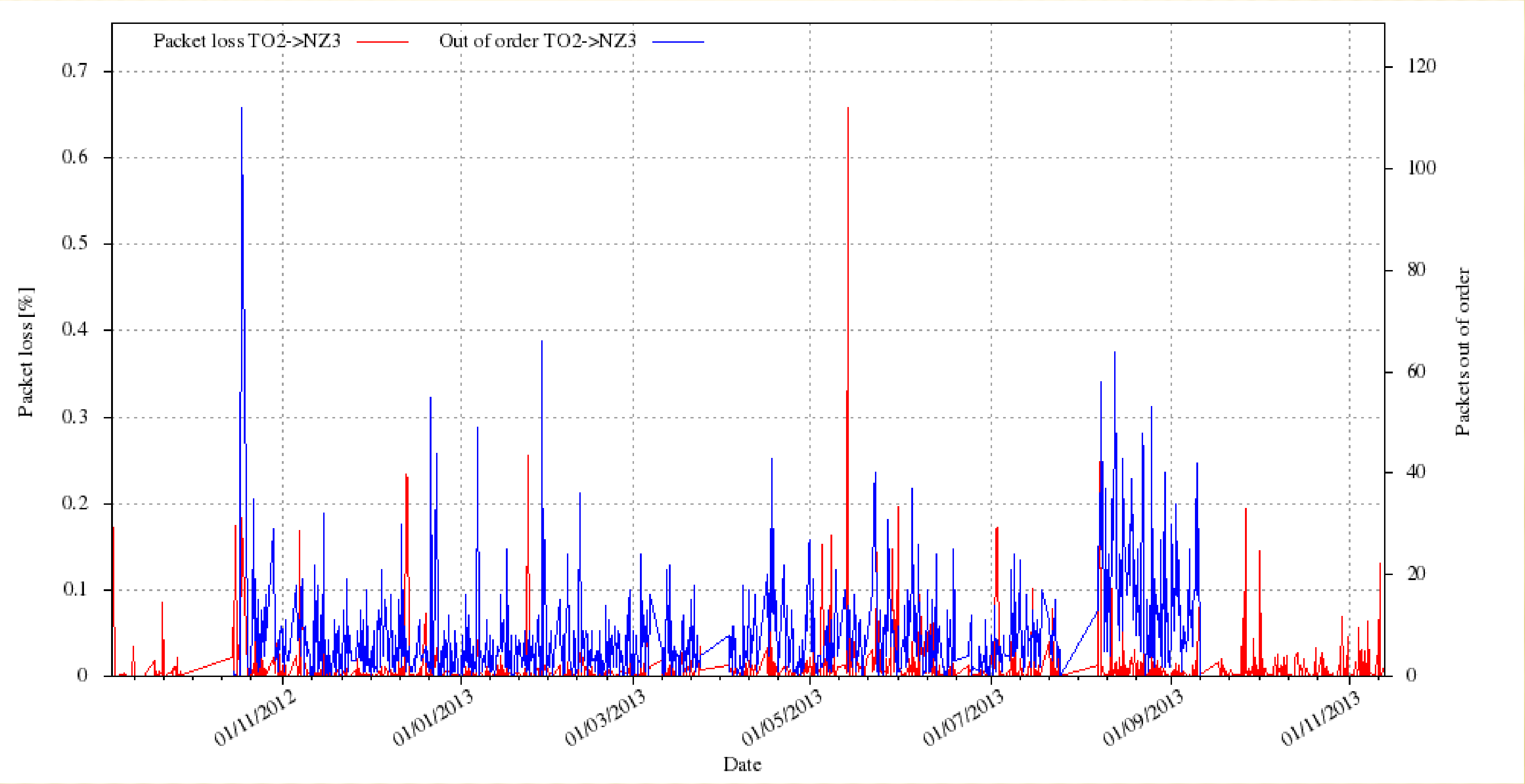
WHY HAVE BEACONS ALL OVER THE WORLD?

- Want long-term global trend, not just local effects
- Want a "developed world" baseline but also see what it is like in remote places on the fringe – many of our beacons run in the Pacific for that reason (need I mention Africa?)
- Long paths generally are of interest – both in terms of latency and number of hops
- A lot of international traffic passes through "hub regions" (North America, Europe, SE Asia). What effect do these regions have on traffic that passes through them?
- Last but not least: We're looking for input from our partners (and their own experiments)!

INITIAL OBSERVATIONS: PACKET LOSS



INITIAL OBSERVATIONS: LOSS VS OUT-OF-ORDER



PACKET TRAIN QUALITY

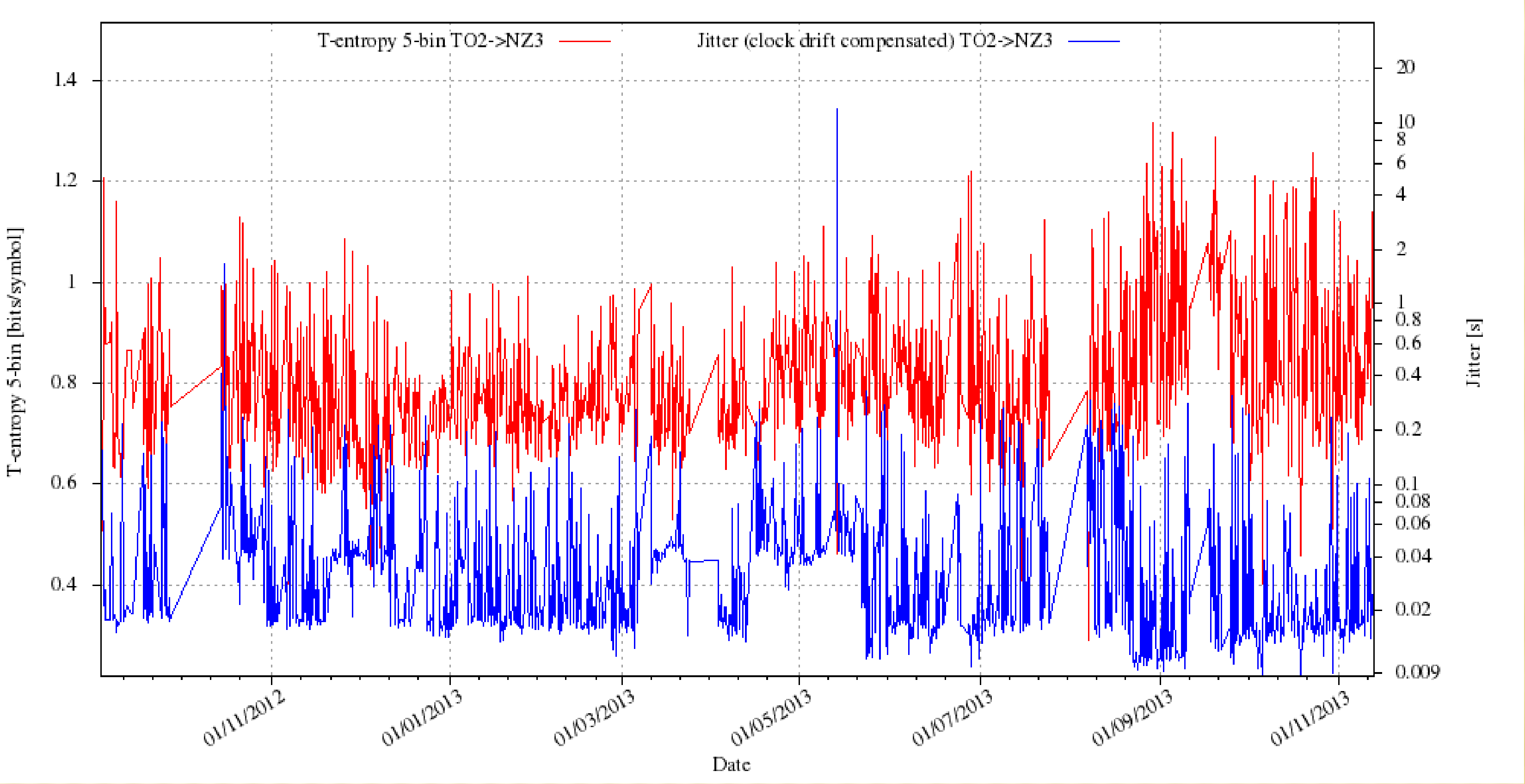
- Subjective approaches, e.g., Mean Opinion Score (MOS) – reliably replicable only with very large sample
- Objective approaches, e.g., jitter measurements.
- But: jitter can be random (=problem) or predictable (=less of a problem)
- How can we tell the difference?

ENTROPY HOW-TO

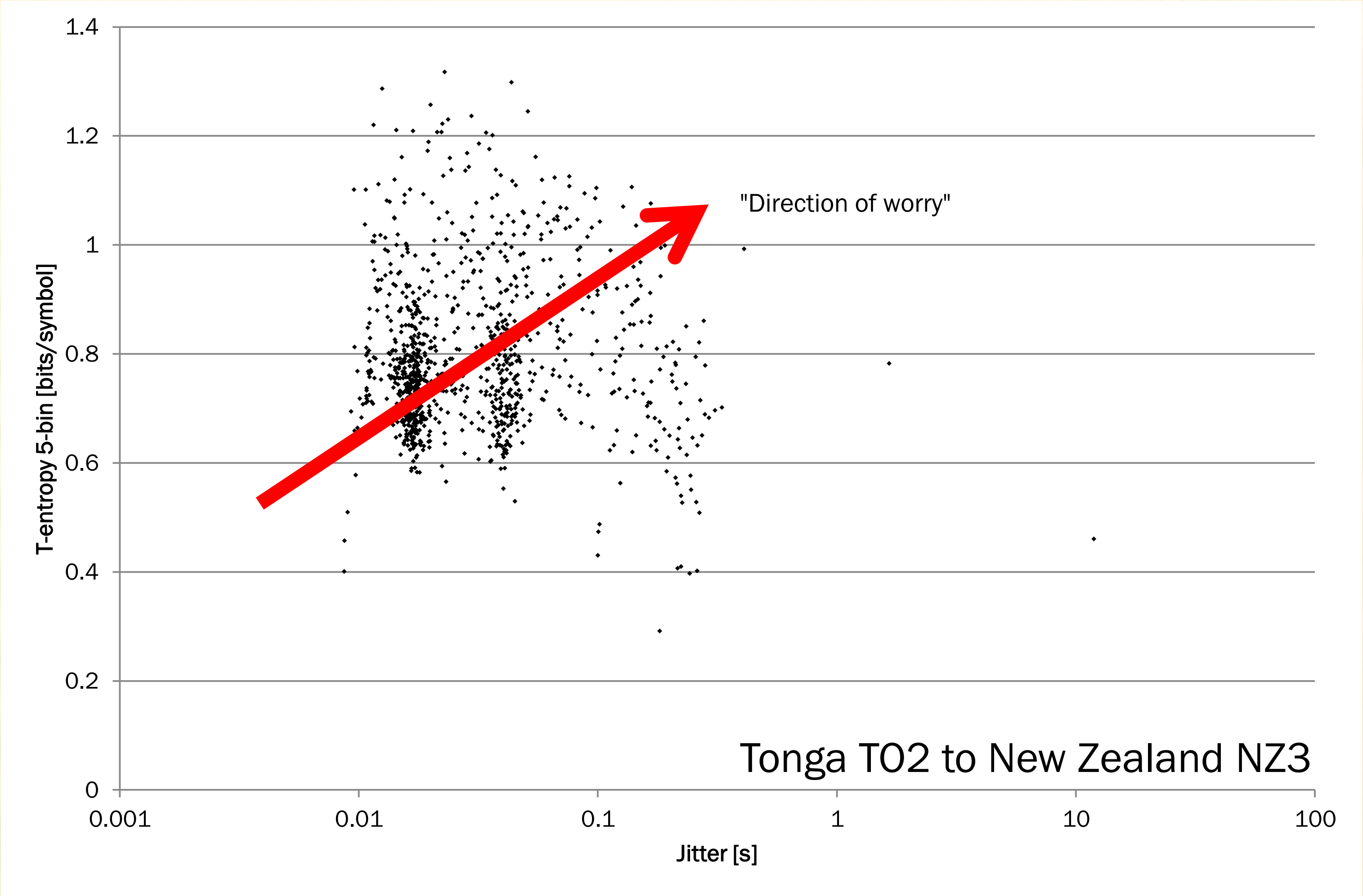
- Map inter-arrival times of successive UDP packets to symbol bins, e.g.:
  - t < 17 ms: "A"
  - 17 ms < t < 19 ms: "B"
  - 19 ms < t < 21 ms: "C"

    …
- Form string from these symbols: "CCCBDCACF…"
- Determine entropy rate for string (e.g., as Lempel-Ziv compression ratio or T-entropy)
- "Perfect" string will be "CCCCCCC…" – highly compressible, low entropy
- Chaotic arrivals generate many new pattern combinations: harder to compress, higher entropy

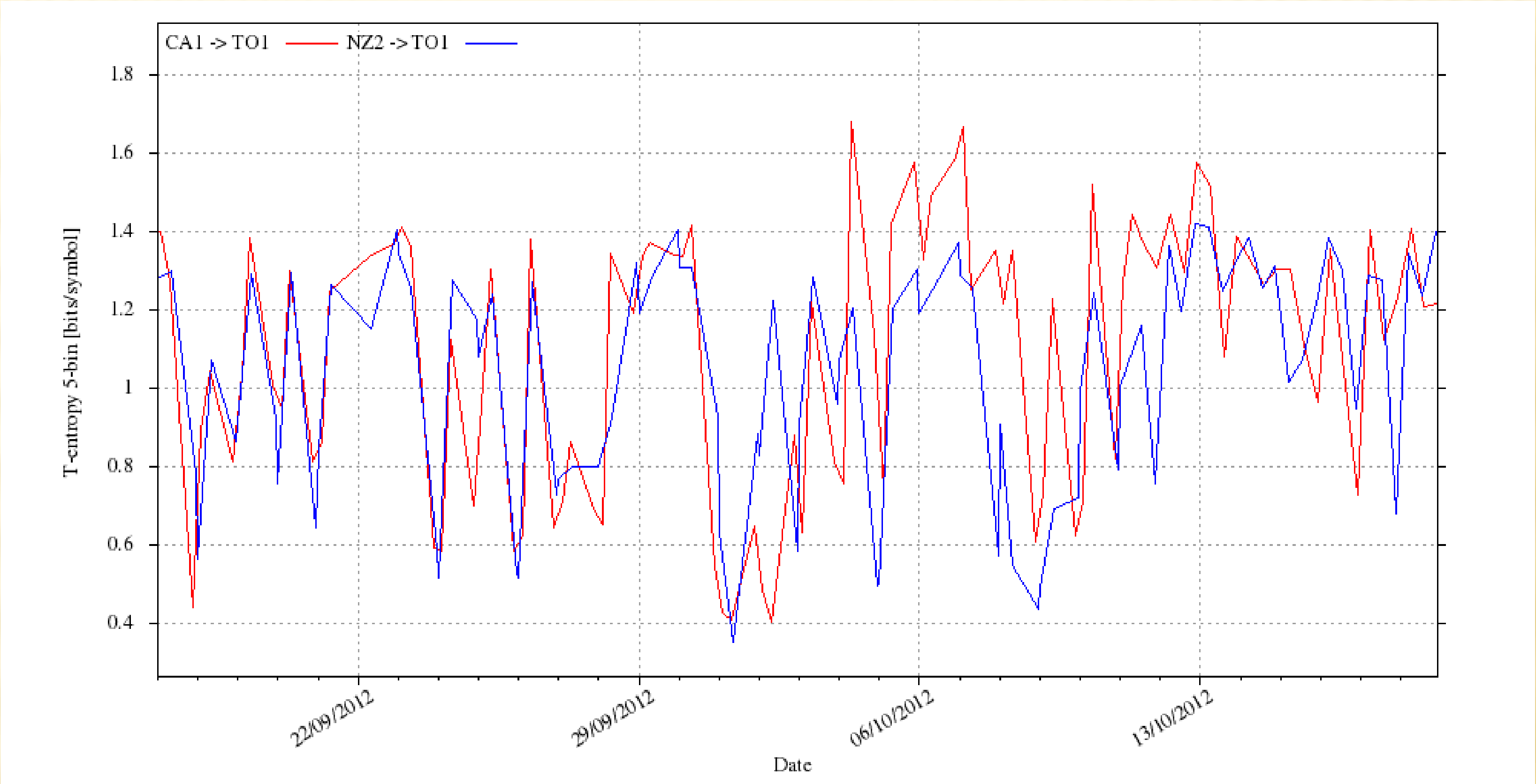
ENTROPY VS. JITTER



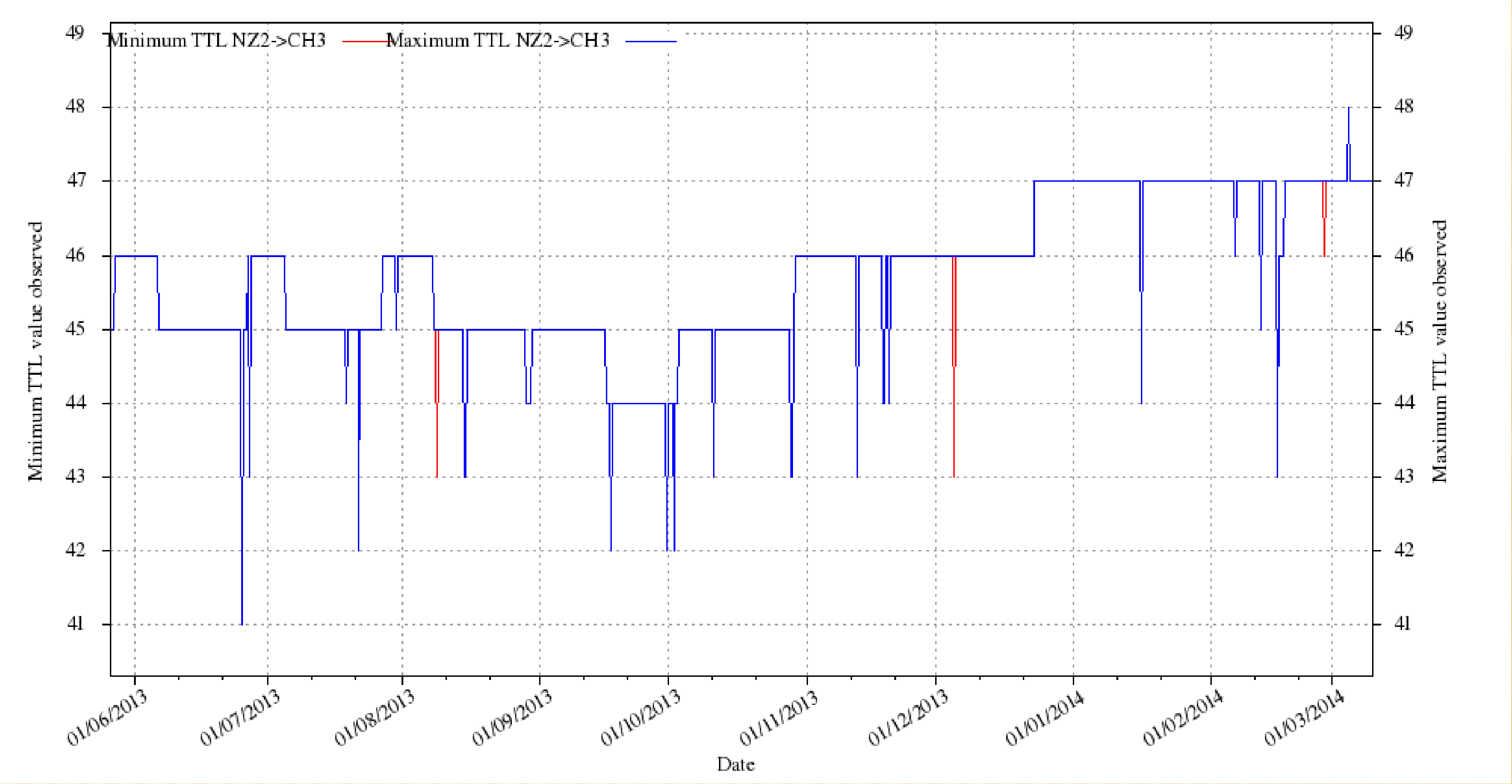
ENTROPY VS. JITTER



WHERE IS ENTROPY INTRODUCED?

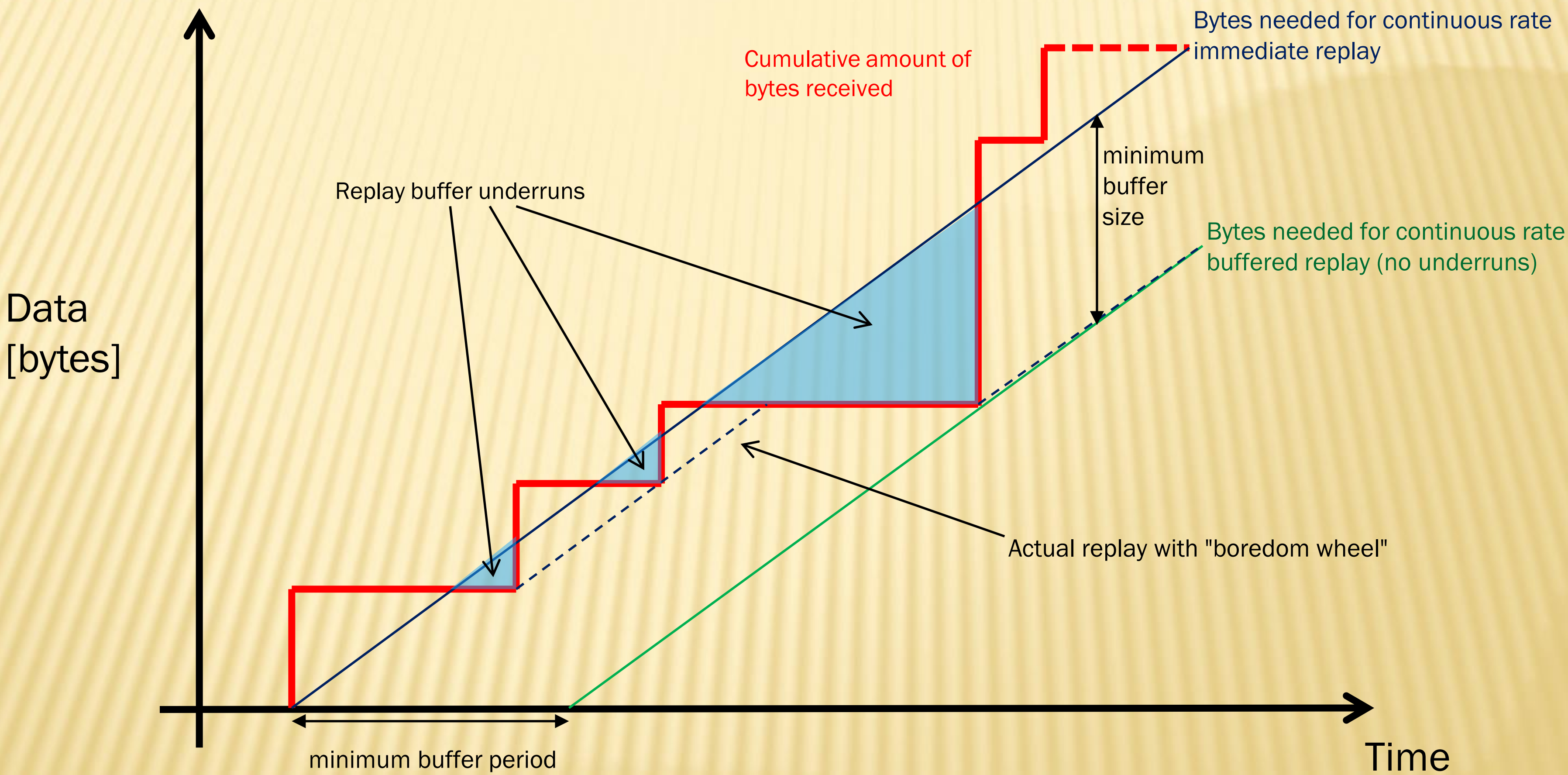


CHANGING TTLS – PROOF OF PATH INSTABILITY



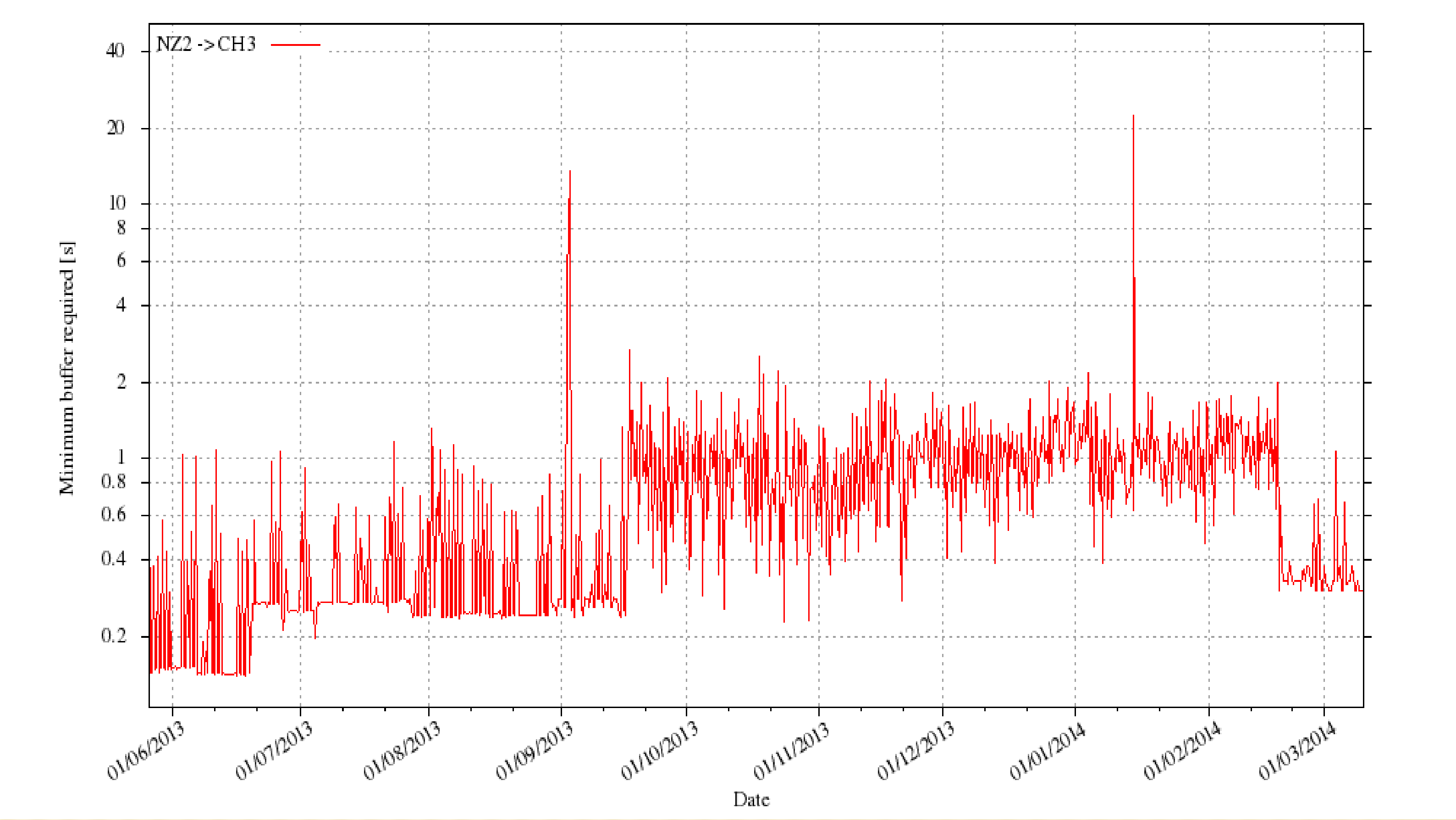
Etuate Cocker - ecoc005@auckland.ac.nz

TCP IN STREAMING APPLICATIONS

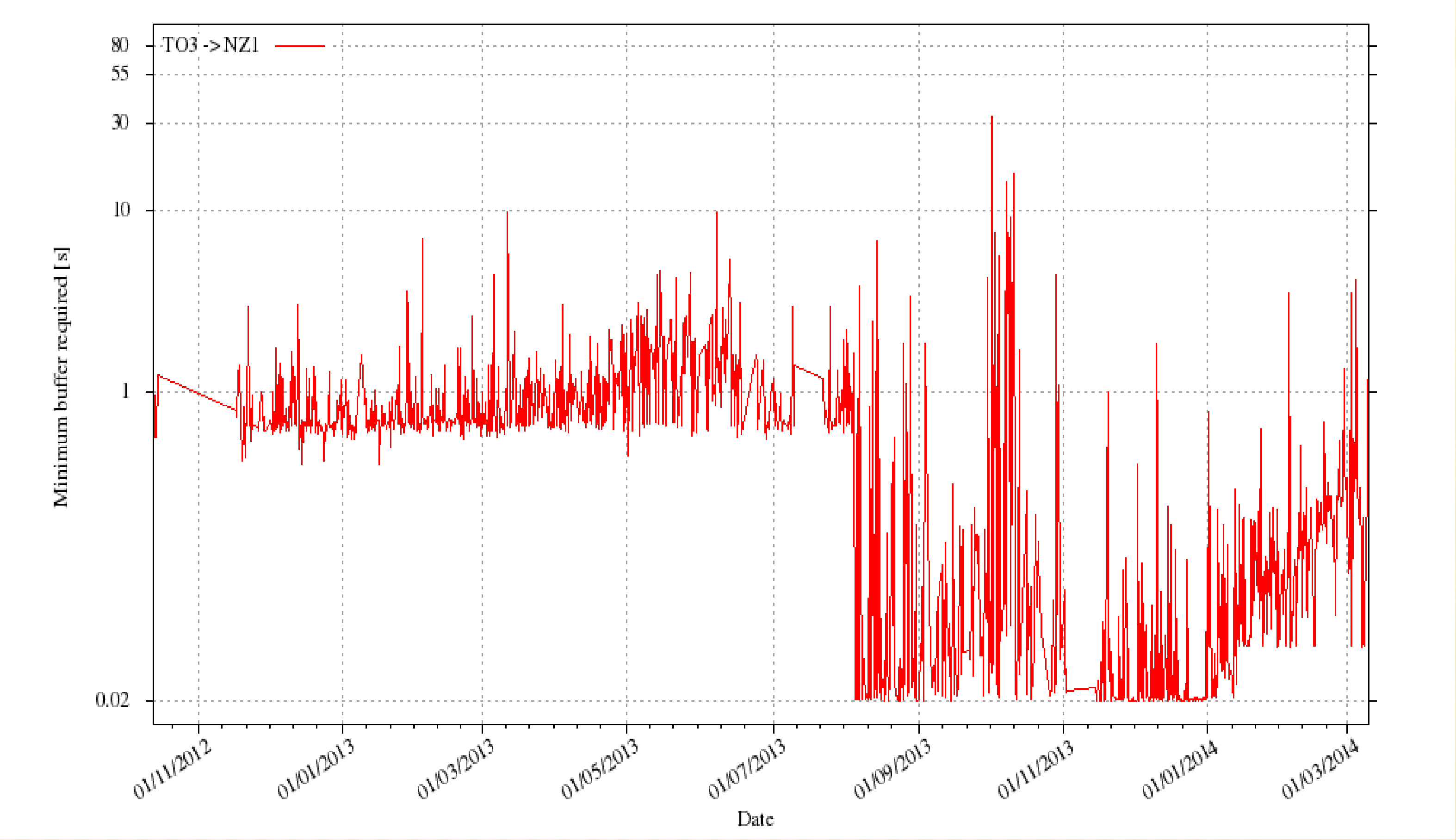


Goal: Avoid buffer underruns with minimum buffer period / size

TCP MINIMUM BUFFER TIME TRENDS?



THERE'S GOOD NEWS FOR … TONGA



CONCLUSIONS

- Real-time traffic and best-effort protocols are uneasy companions
- Lots of experiments with synthesized traffic modelled on real-life applications can get us an idea of how sustainable real-time protocols really are
- Our beacons already see interesting effects, often strongly path-specific and sometimes not easily explained – need to observe for much longer
- Big data: ~0.5 GB of uncompressed beacon log files / day
- A lot of work remains to be done!
- Ask us if you're interested in hosting a beacon
- https://iibex.auckland.ac.nz

Questions ?

https://iibex.auckland.ac.nz