Measuring the Quality of Real-Time Internet Traffic

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Overview

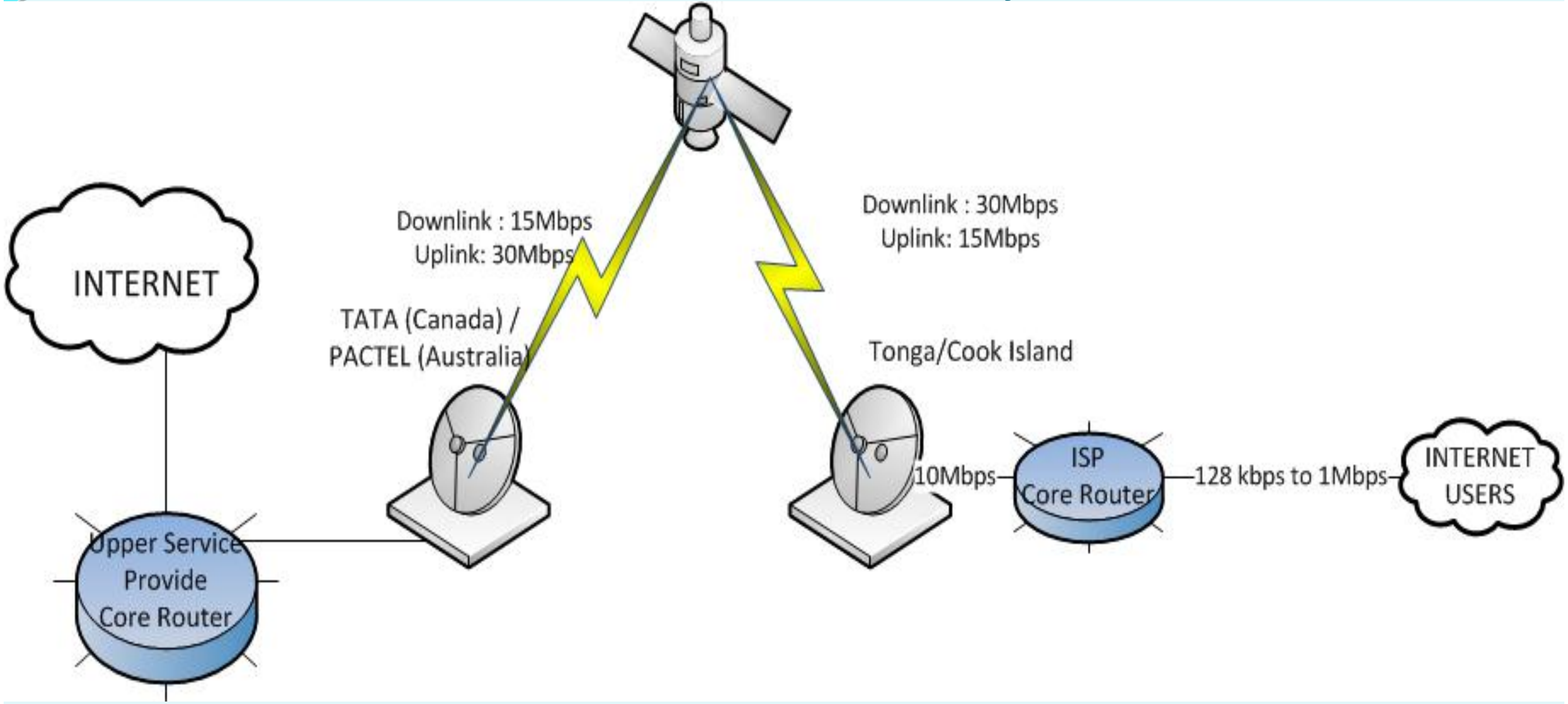
- Typical low bandwidth and high latency networks in the Pacific Islands
- Measurement of jitter and entropy for voice and data transmission in high latency and low bandwidth networks
- Possible solution strategies

Pacific Island Countries (PICs)

- Region spread across 33 million square kilometres of ocean.
- Home to 22 countries. Consist of 1118 inhabited islands, many barely above sea level.
- Each country has less than 25% of population with access to Internet. Internet available in work places, educational institutions and public facilities.

Source: Ministry of Lands in Tonga

International Connectivity in PICs



- Internet connectivity is possible with high latency satellite links to TNZI in NZ, TATA in Canada, PACTEL in Australia.
- Maximum downlink less than 30Mbps; uplink of approximately 15Mbps for whole country. Customers purchase bandwidth from 56Kbps to 2Mbps.
- Fibre optic submarine cables only in few places such as New Caledonia,

Last Mile Internet Connectivity in Pacific Island Countries

- Old routers used to connect to Internet

- Updated your firmware lately?

- Old computers without antivirus or security updates

- Poorly maintained phone cables used to connect customers, with few ADSL subscribers

Source: Ministry of Lands - remote solar centre

So…

- Old overloaded infrastructure communicates over links with little bandwidth and a lot of unwanted traffic.
  - Long router queues/high packet loss
  - Possible multipath on international links
- This means: packets that we transmit at regular intervals (such as in a VoIP stream) don't necessarily arrive at regular intervals – or at all
- This means VoIP and other real-time protocols don't work that well in the Pacific
- Can we measure this objectively?

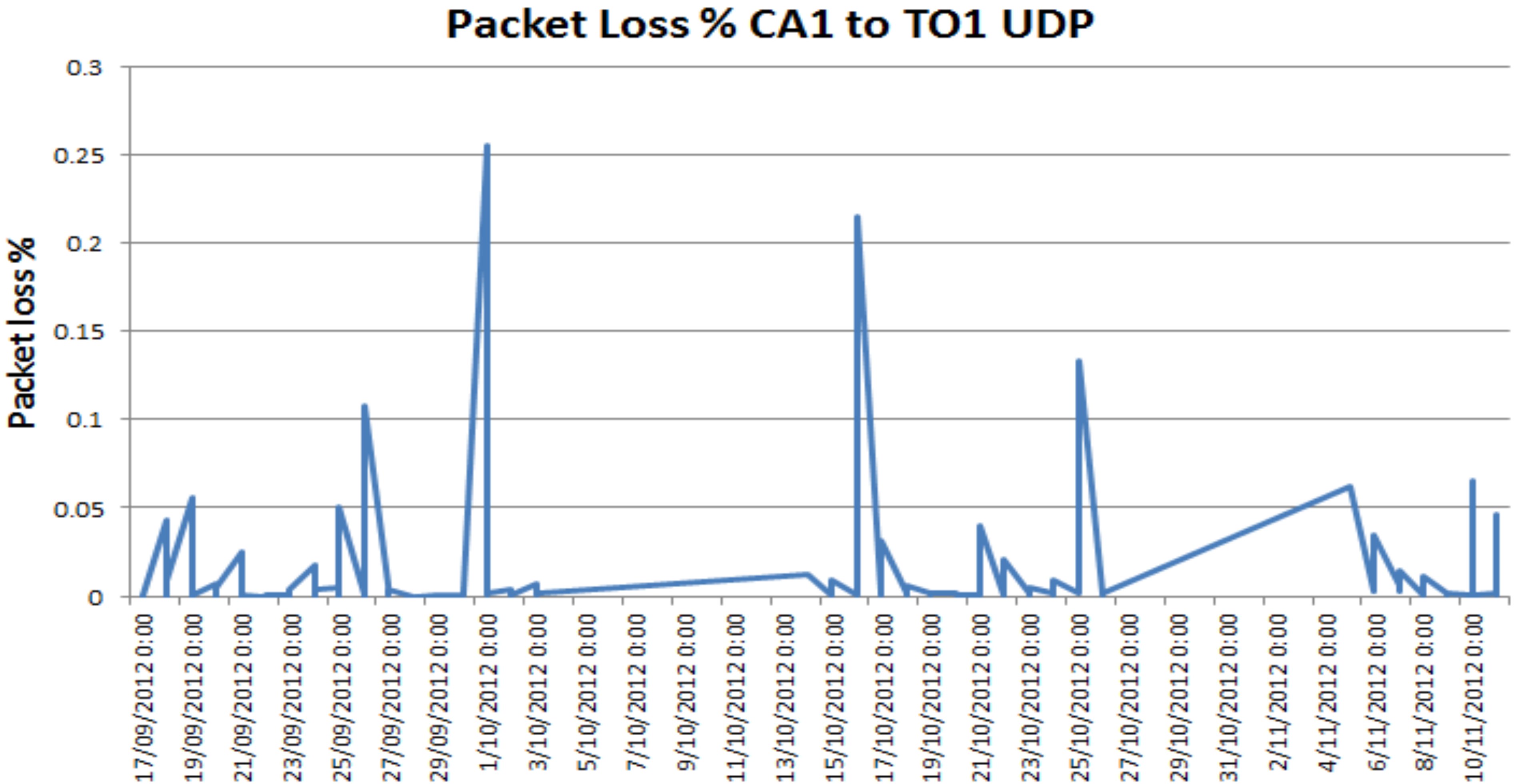
Our Beacon Network

URL: https://130.216.5.147/

What the Beacons do

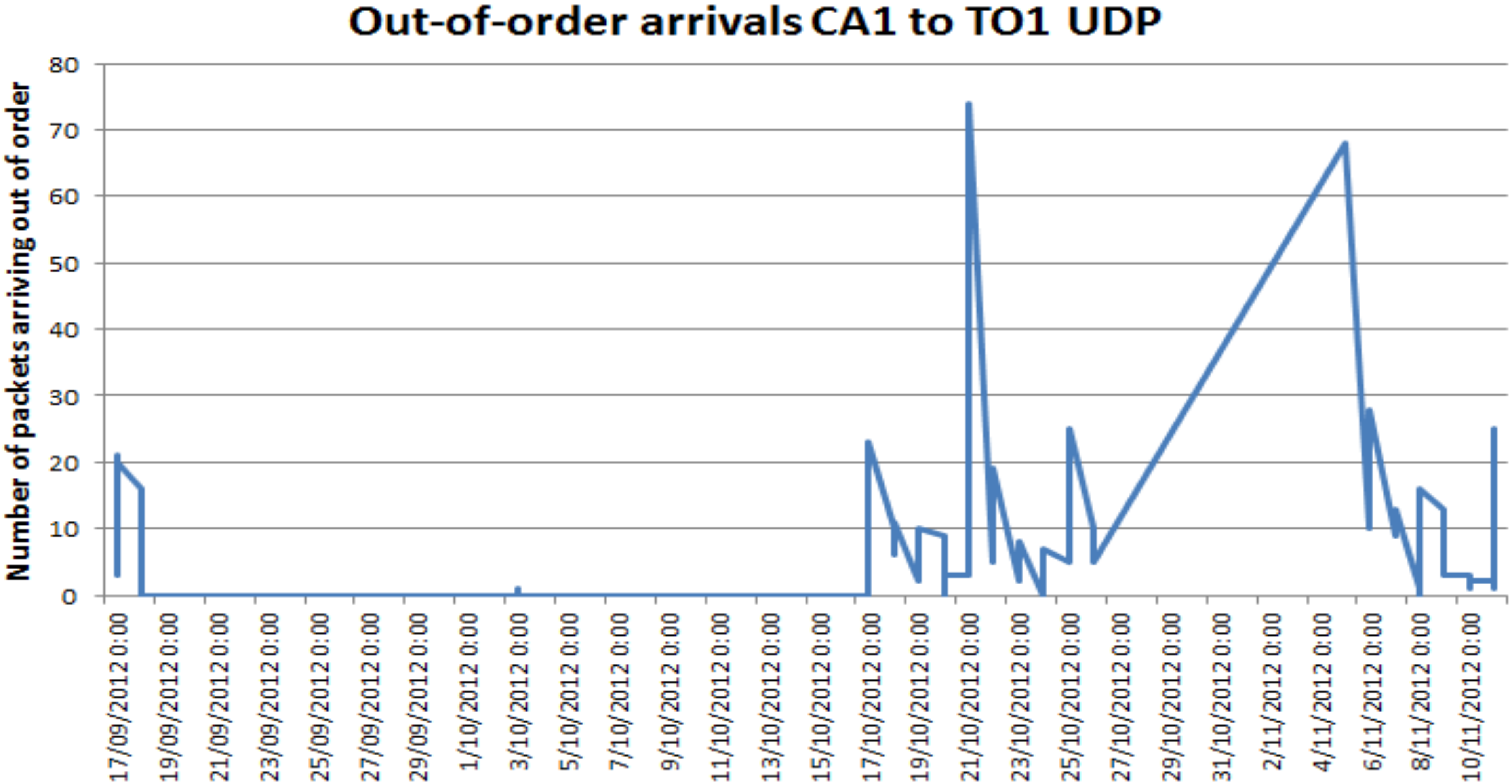
- Work in pairs to exchange synthesised traffic
  - UDP: VoIP-like stream of numbered and timestamped packets
  - TCP: VoIP-like constant data rate stream
  - TCP: Download-like maximum data rate stream
- Log packet/data arrival time plus TTL at receiver
- Also log transmit queue time and dequeue time
- Logs retrieved to central repository for analysis and archiving

Example – Packet Loss



- We determine packet loss % by 100 * (total sent – total received) / total sent
- Note: 10,000 packets transmitted per experiment run

Example: Out-of-order arrivals



- We simply go through log files and look at received sequence numbers to find out if packets were reordered as they travelled from source to destination.
- Note: 10,000 packets transmitted per experiment run

Question

What is Jitter?

Jitter

- Jitter is the variation in packet travel times and / or packet arrival times

- Different definitions exist

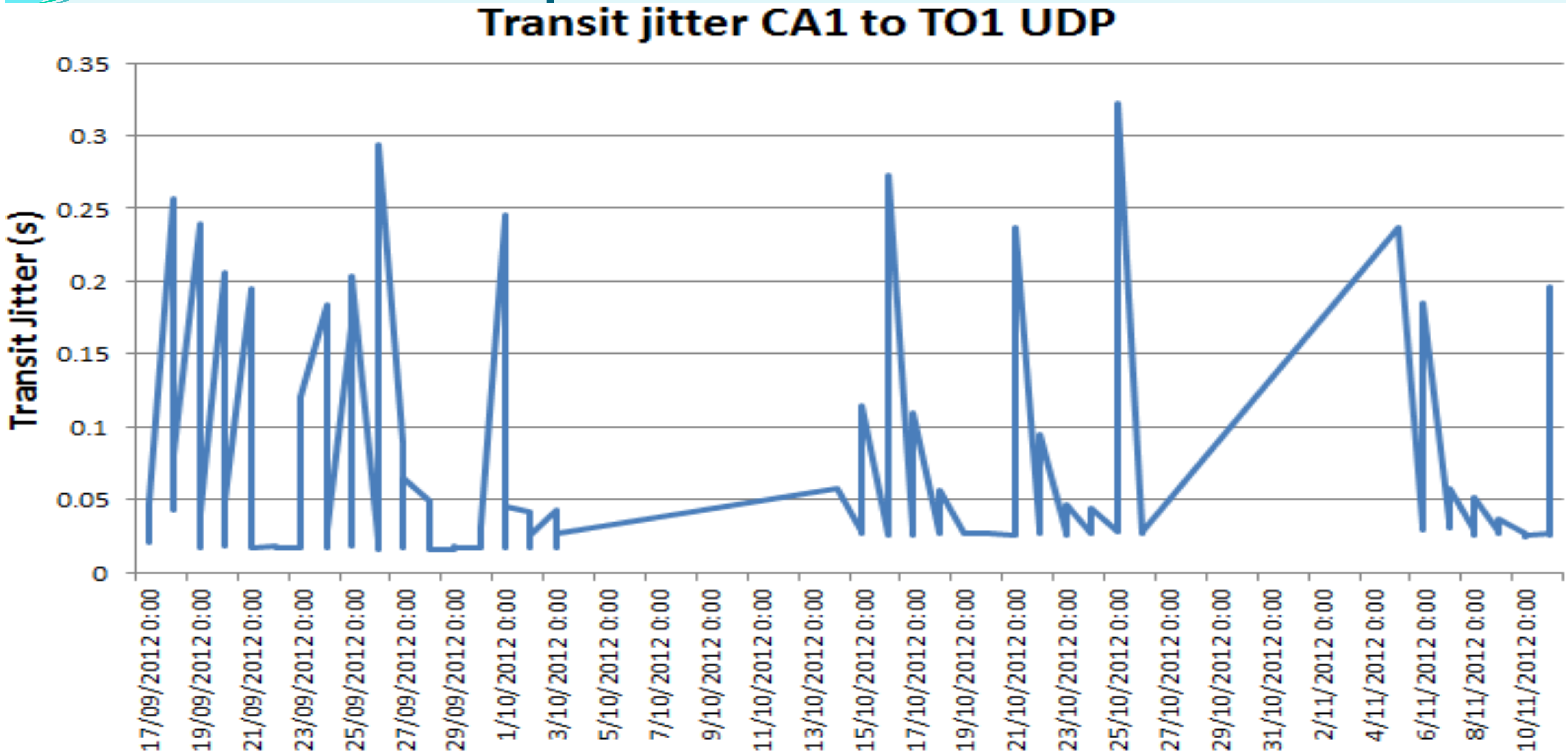
Measurement of Jitter

- E.g., beacon software transmits and receives synthesised UDP packets with sequence numbers and timestamps every 20 milliseconds (10,000 packets in one experiment)

- 3 experiment runs per day

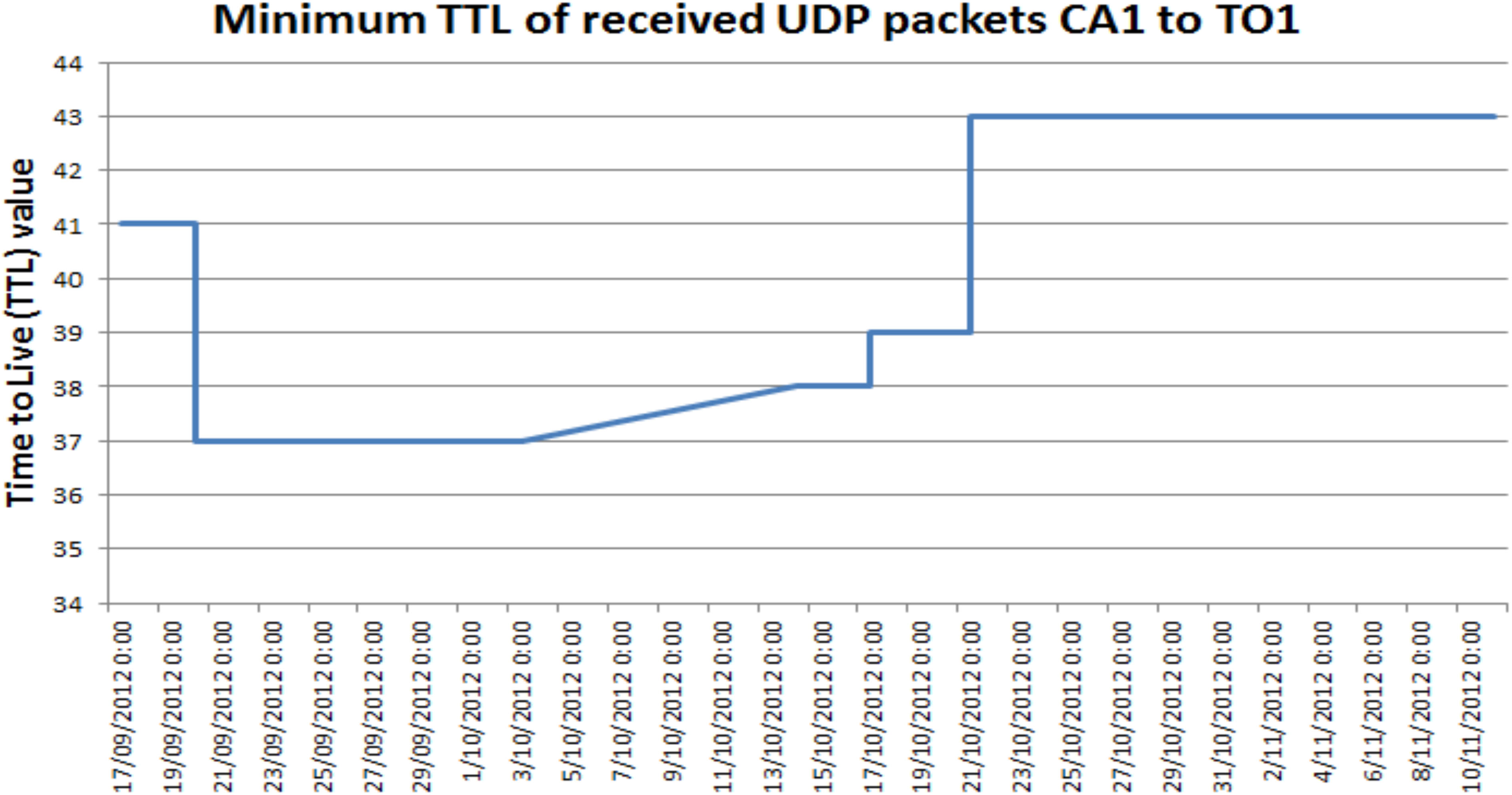
- Compute jitter from timestamps logged

Example: Transit Jitter



- Transit jitter measures the variation in the difference between transmit and receive timestamps

Example: Packet pathways - TTL



- Even though we recorded no changes in TTL for a single log file, We can see changes in packet pathways when projecting multiple log files.

Packet Train Arrival Entropy

- What is entropy?
  - Predictability of arrival timing
  - Recurring patterns in arrival timing
- Provide example of entropy

Entropy Measures

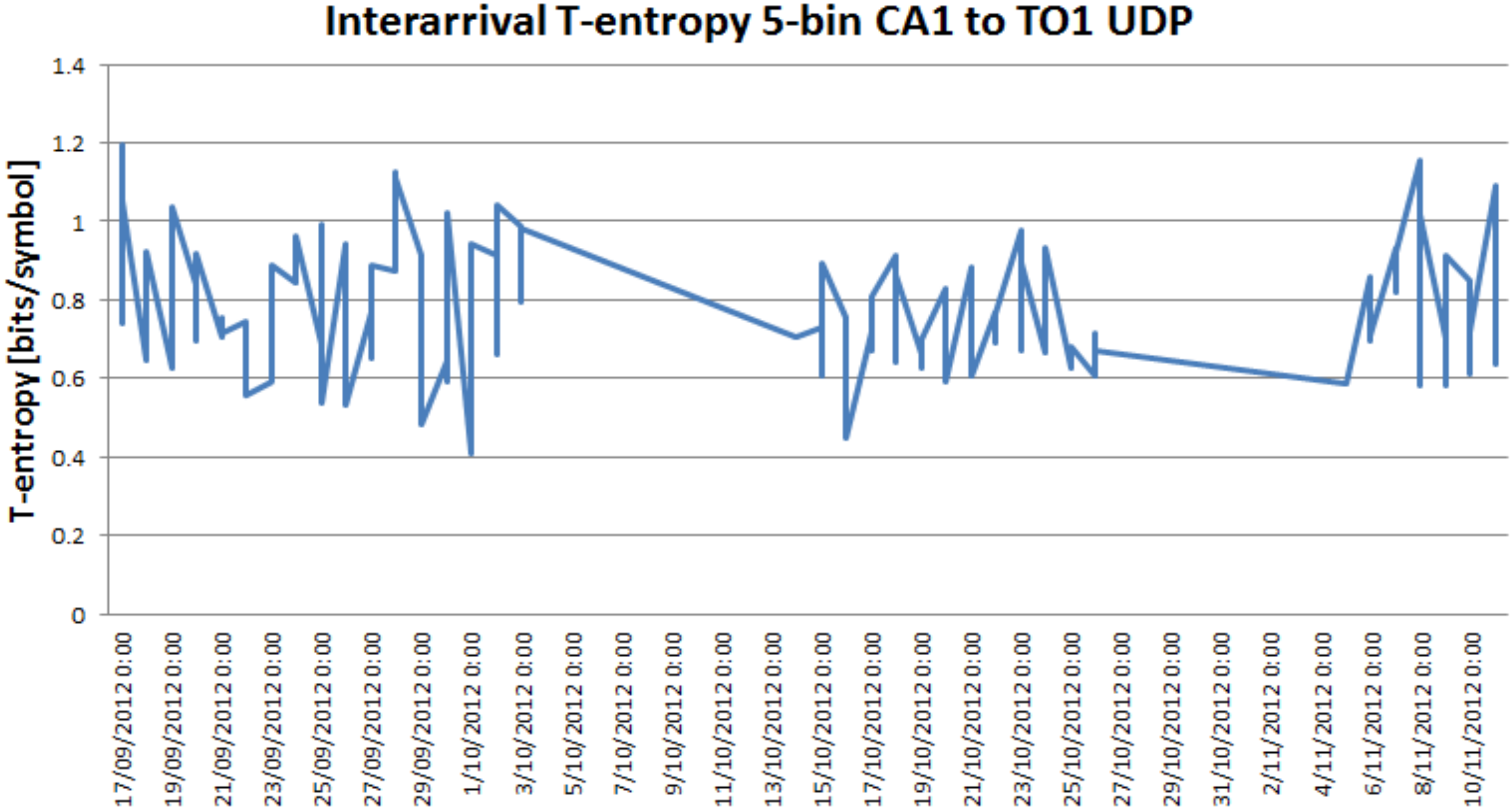
- Need to produce a string (or sequence of symbols) – think of this as a Shannon "source"
  - E.g., We have the following threshold
  - A = inter-arrival time 0- 15ms
  - B = inter-arrival time 15-18ms
  - C = inter-arrival time 18-22ms
  - D = inter-arrival time 22-25ms
  - E = inter-arrival time > 25ms
- Then map inter-arrival times to symbols to get the following results

Packet no.i	Arrival timestamp (ri)	Difference Inter-Arrival Time	Symbol
0	(packet lost)		
1	1348001461.691		
2	1348001461.717	26	E
3	1348001461.738	21	C
4	1348001461.760	22	C
5	(packet lost)		
6	1348001461.821		
7	1348001461.828	7	A
8	1348001461.848	20	C
...	...	...	...

Computing Entropy

- Then: Compute entropy from string (Shannon, T-entropy, LZ compression ratio)
- Entropy is able to classify more complex patterns as 'normal' that pure jitter measures would consider random
- The example on the previous slide maps to x = ECDEAC… That's a hard sequence to predict
- If we receive a packet every 20 ms, the string is CCCCCC… Very predictable!
- Our "real" strings are up to 9999 symbols long!

Example: Inter-arrival T-entropy



- Entropy didn’t change much over our observation period so far – despite the major changes in the number of routers we’ve seen

Beacons Long Term

- Trends in jitter: Will jitter increase or decrease over time?
- Trends in TTL: Will multipath propagation increase as additional links are added?
- Trends in entropy: Will arriving data streams become less predictable?
- Intend to measure for many years to come

Possible Solution Strategies

- Install anti virus and personal firewall at end user's computers. (costly, manpower)
- Build better voice codecs. (costly, challenging)
- Filter viruses/worms at Internet Service Providers (ISPs) (process overhead and introduces more delay, costly)
- Improve Quality of Service (QOS) at ISPs (costly, skills)
- Increase bandwidth with fibre optic cables (costly)
- Use network-coded TCP (new!)

Network-coded TCP

- Network coded-TCP developed by colleagues at Massachusetts Institute of Technology (MIT).
- Linear combinations of packets are transmitted at once.
- Provides redundancy for packet recovery.
- Fewer retransmissions of packets.

Example ("+" means XOR):

Data packets: A, B , C

Transmit A, B and C as network coded packets 1 to 4:

packet 1: A + B + C

packet 2: A + B

packet 3: A + C

packet 4: A

Network-coded TCP

- Receiver
- Assume packet 1 (A + B + C) goes missing:
  Can decode A as: 4 = A
  Can decode B by: 2 + 4 = A + (A + B) = B
  Can decode C by: 3 + 4 = A + (A + C) = C

- Assume packet 2 (A + B) goes missing:
  Can decode A as: 4 == A
  Can decode B by: 1 + 3 = (A + B + C) + (A + C) = B
  Can decode C by: 3 + 4 = (A + C) + A = C

Conclusions

- Beacons provide tool for monitoring the long term development of jitter and entropy

- Network-coded TCP represents a possible solution for improving flow over high latency and low bandwidth links

Thank You

Question?