First Impressions on the State of Cellular Data Connectivity in India

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Paper Review*

1. Key Research Aim

An attempt to build an understanding of cellular data connectivity in India with the larger goal of improving end-user experience by evaluating availability, throughput, latency and other network characteristics of four cellular service providers across seven locations over a period of 3 months.

2. Motivation

Below are the key problems that highlight the need of research in this field and hence the motivation of the paper:

- Little understanding of performance of cellular data connectivity in India.
- While cellular data networks in the developed world have been studied considering data usage and TCP performance on 3G/4G networks, such studies have not been performed in India.
- In the absence of systematic studies and with cellular service providers always advertising maximum achievable physical data rate, one is left to rely on anecdotal evidence and hearsay.

Hence the paper aims to develop a robust, scalable, and extensible suite to conduct active client side measurements in rural regions and provide key insights about cellular data networks in India.

3. Cellular Data Technologies

In this section, the paper talks about history of cellular data technology evolution in India. Explaining briefly it tells us the 3GPP and 3GPP2 program and introduces 2 families mainly GSM family and CDMA family. It then tells the evolution of these families from 2G to 3G(including 2.5G and 2.75G) and hence listing all the technologies. Below is the table in the paper which lists all the technologies in evolution order:

Group	Family	2.5G	2.75G	3G
3GPP	GSM	GPRS, HSCSD	EDGE	WCDMA, HSDPA
3GPP2	CDMA	1xRTT		1xEV-DO

4. Assumptions

Below are the prior facts or assumptions accepted based on previous work in related area:

- Small initial congestion window combined with large RTT (>1000ms) causes ineffective use of available bandwidth as it takes a long time to fill the network pipe during slow start and hence impacts small file transfers. Large buffer sizes at gateways, a phenomenon nowadays referred to as "buffer bloat", causes large delays in interactive applications and TCP SYN timeouts during new TCP flow creation.
- Delay characteristics of latencies depend mainly on network conguration rather than location or measurement device.
- Cellular network deployments may vary across countries and service providers.
- HSDPA provides an improvement in TCP throughput over WCDMA, but the improvement is modest, particularly for short dura-

*REFERENCE URL: `http://www.cse.iitd.ernet.in/~aseth/cellular_data_connectivity_india.pdf`

tion flows which is attributed to large RTTs compared to wired networks and small initial congestion window size.

- Measurement architecture design draws upon prior work by Kreibich, borrowing the key concept of having a separate control server to serve the tests to be conducted by the client.

Many of the facts above are based on studies which are more than 10 years old and hence many of the facts may not apply in present time.

5. Methodology

5.1. Setting-up

Broadly there were 2 challenges in setting up. First is the selection of location in rural India and second is to design a measurement architecture consisting of appropriate hardware and software that can be deployed in rural location, require minimal manual intervention, and efficiently cope with the challenges of electricity outages, rodents in the building chewing cables, and minimal technical support. With the help of a NGO, six rural and one semi-urban location were chosen. For urban location, Delhi was chosen. 4 service providers namely BSNL, Airtel, Idea and Reliance were chosen for measurements.

5.2. Architecture

Measurement clients are low cost netbooks provided with 3 USB modems. The measurement client is configured with a unique node ID and information about the service providers and corresponding access technologies to be used. For each (client id, service provider, access technology) tuple, the client requests a control server for a list of tests to be conducted.

The control server maintains the list of tests to be conducted for any given (client id, service provider, access technology) tuple. In response to a client request, the control server sends a list of tests.

The measurement server is well provisioned (in terms of bandwidth) and it is primarily used as the remote node for conducting throughput tests.

The results of all the measurements are uploaded by the clients to a data server. Packet level traces from the measurement server are also sent to the data server.

5.3. Monitoring

- A heartbeat system that periodically sends netbook battery life information, signal strength, and connection status of the three modems to the control server.
- If the control server does not receive the heartbeat UDP packets for a threshold amount of time, it sends an alert mail.
- A daily reporting system that sends a summary of successful tests at each client.
- An alert system to report if a USB modem is detached from the client netbook as a security feature.
- A system to track cellular data usage.

6. Test Results

6.1. Availability

There are 2 aspects namely type of connectivity and availability:

- Only EDGE/1xRTT connectivity is available in rural locations, the semi-urban location is found to transition between EDGE and HSDPA, the urban location had continuous HSDPA/1xEV-DO connectivity for all the evaluated service providers.
- In terms of percentage of duration in which internet connectivity is available, availability in rural locations is 15 % lower than urban location with an exception of Reliance CDMA network whose availability is below 50 % for both rural and urban locations.

6.2. Throughput

- The achieved throughputs are signicantly lower than their theoretical maximums.
- In brief higher throughputs are observed for every network in both the uplink and downlink directions at night(10pm to 6am) than day(9am to 6pm).
- Throughput on weekends is lower than on weekdays for urban location accounting to more leisure activities on weekends. No such change is observed for rural locations.

- No correlation between throughput and signal strength.

6.3. Latency

The EDGE connections for different rural locations give different latencies and hence are not a property of EDGE air interface rather a result of network configuration. Significantly lower latencies are observed for Reliance 1xEV-DO network. A 50 % reduction in latencies is observed for in-network IP addresses with those to outside-network IP addresses.

6.4. Network Architecture

- No firewall deployments were found within service provider network. This avoids potential performance degradation but exposes clients to attacks. Also, no evidence of in-network virus detection.
- None of the service providers employ HTTP proxies or web caches. Service providers can improve end user experience by employing web caches in their networks.
- Service providers appear to use only a few gateways(<5). Content providers can use this information to optimize end-user experience by carefully placing content close to the gateways.
- Airtel seems to allocate additional resources to service clients in the urban location. 2 out of the 3 gateways observed are only seen in the urban location's 3G connection. The urban location's 2G connection has higher throughput and lower latency compared to Airtel's 2G connections in other locations. DNS lookup times are also found to be lower in the urban location's 2G connection.

7. Connection Stall

During the packet trace analysis there were several instances where the data transfer stalled for a long period of time due to multiple re-transmission timeouts of the same packet. The sender times out and re-transmits several times the first lost packet before it is acknowledged. This phenomenon of flow stall due to timeouts is called connection stall.
Connection stalls decrease throughput in 2 ways: First, sender detects the time-out event as congestion and reduces the congestion window size which in turn reduces throughput. Secondly, long period of inactivity in the flow also impacts the achieved throughput.
The stalled state took about 15 % and 6 % of time of the total iperf test duration in 2G and 3G respectively.
On several experiments virtual Machines running the server, client hardware, reduced signal strength don't have any impact on stall events.
A few reasons like buffer bloats can be accounted for stalls but they do not explain it completely. Another observation is that stalls occur when there is a bursty transmission of data. A possible solution to decrease stall time is to decrease receive window size but it also reduces the throughput significantly whereas the ultimate aim is to increase throughput.

8. Repeating Experiments Today

India has largely shifted to 4G network and there is a lot less gap between urban and rural areas due to a lot of urbanization and more coverage by different service providers. Moreover the architecture is bound to not give good results in the current scenario since much more complicated and more secured ways have come up in cellular connectivity. Doing the same experiment today will also have very less traffic since 2G is almost extinct in the present Indian scenario. A much more complicated though not so robust architecture will be needed for today's scenario since we don't need to tackle power outage issues etc.

9. Key Takeaways

There is significant difference between rural and urban cellular connectivity both in types and latencies and also between Indian and developed countries connectivity status. Also, considering the architecture there were some notable points like it was a robust model which can even detect cutting of cables due to rodents, data limit issues etc. Using a central server and keeping it separate from the measurement server also has many advantages like we can issue multiple tests at a go and can safely monitor in all the results with the heartbeat approach. Lastly, we could not figure out exactly why the connection stall took place and consequently decrease stall time which is a topic of further research.