

# Need, Want, or Can Afford - Broadband Markets and the Behavior of Users

Zachary S. Bischof, Fabian E. Bustamante,  
Rade Stanojevic  
Presented by Thomas Morreale

# Research Goals

Understand what factors affect user demand for broadband access.  
The main factors investigated are:

- Capacity
- Cost of broadband access, as well as cost to upgrade.
- Latency and packet loss

# Datasets

- 53,000 end-hosts and residential gateways in 160 countries
- Dasu (end-host)
- SamKnows/FCC (gateway)
- Google's "Policy by the Numbers" (global survey of retail broadband plans)

# Natural Experiments

- Test/Control Experiment not exactly possible at scale on Internet
- “Natural Experiments” - pairing the data
- Caliper - no more than 25% difference in the pairs.
- Only accept outcomes where the standard deviation is greater than 2%.
- “Geek Effect”

# Impact of Capacity

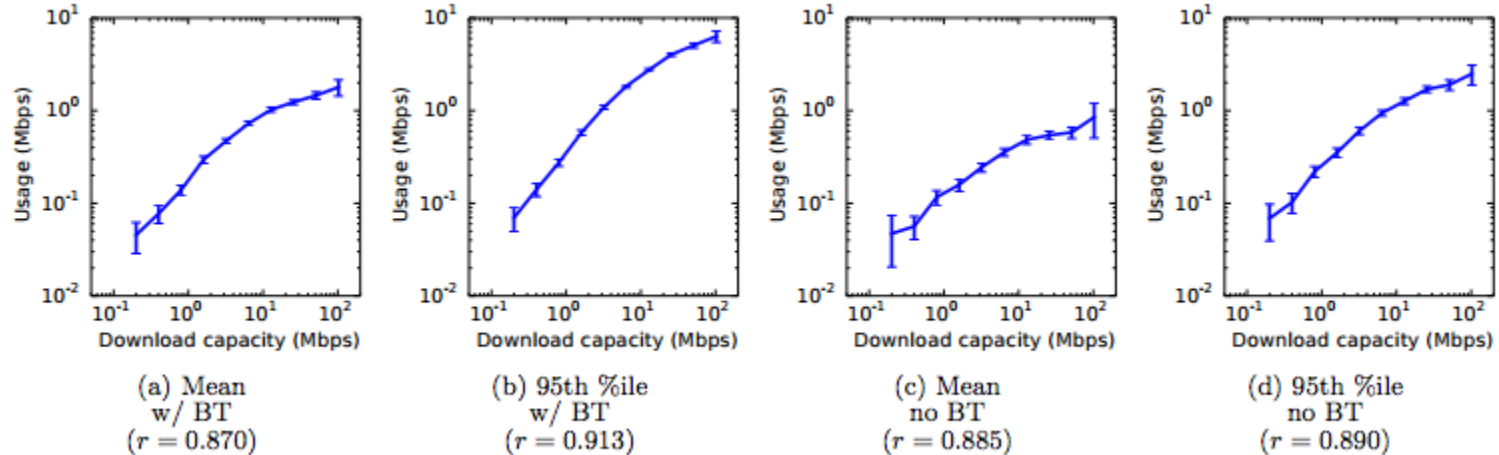
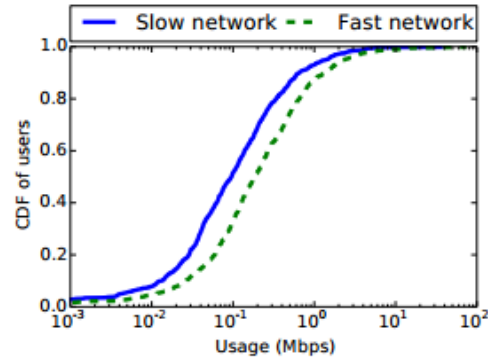


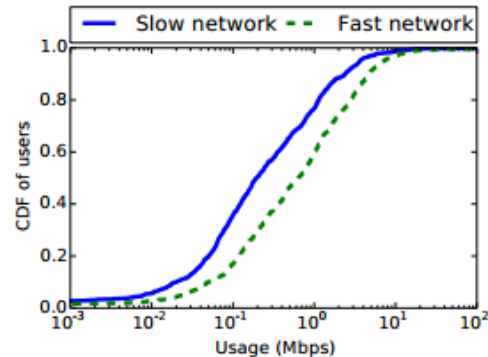
Figure 2. Volume of download traffic generated by users versus their download link capacity.

Lower capacity connections have a higher relative increase in demand.

# Upgrading Capacity



(a) Mean



(b) 95th %ile

# Upgrading Capacity

Metric	% $H$ holds	p-value
Average usage	66.8%	$1.94 \times 10^{-25}$
Peak usage	70.3%	$1.13 \times 10^{-36}$

Selecting pairs that were similar in terms of price, cost to upgrade, and link quality, but differ in terms of service capacity, we can see that “faster” networks (higher capacity) have higher demand.

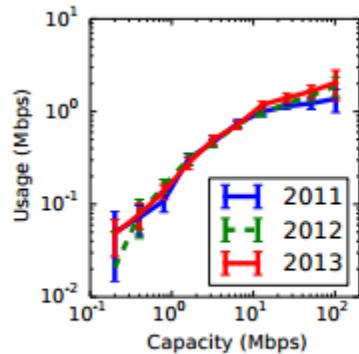
# Diminishing Effect

Dasu data			
Control Group (in Mbps)	Treatment Group (in Mbps)	% <i>H</i> holds	p-value
(0.1, 0.2]	(0.2, 0.4]	75.2%	$5.81 \times 10^{-11}$
(0.2, 0.4]	(0.4, 0.8]	63.4%	$2.21 \times 10^{-7}$
(0.4, 0.8]	(0.8, 1.6]	59.9%	$8.01 \times 10^{-8}$
(0.8, 1.6]	(1.6, 3.2]	59.3%	$1.11 \times 10^{-8}$
(1.6, 3.2]	(3.2, 6.4]	53.3%	0.0166
(3.2, 6.4]	(6.4, 12.8]	57.5%	0.00707
(6.4, 12.8]	(12.8, 25.6]	56.8%*	0.0583
(12.8, 25.6]	(25.6, 51.2]	52.9%*	0.310
(25.6, 51.2]	(51.2, 102.4]	51.0%*	0.462
FCC data			
Control Group (in Mbps)	Treatment Group (in Mbps)	% <i>H</i> holds	p-value
(0.4, 0.8]	(0.8, 1.6]	66.4%	0.000223
(0.8, 1.6]	(1.6, 3.2]	58.1%	$4.70 \times 10^{-5}$
(1.6, 3.2]	(3.2, 6.4]	56.2%	0.000487
(3.2, 6.4]	(6.4, 12.8]	55.1%	0.00236
(6.4, 12.8]	(12.8, 25.6]	58.5%	$2.54 \times 10^{-7}$
(12.8, 25.6]	(25.6, 51.2]	61.2%	$6.76 \times 10^{-17}$
(25.6, 51.2]	(51.2, 102.4]	64.7%	0.00161

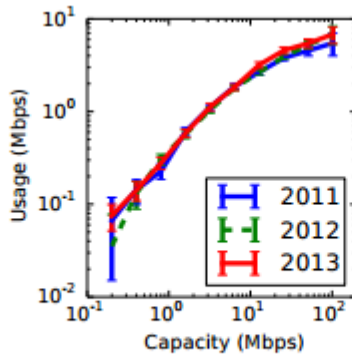
As capacity is increased beyond about 10 Mbps, we begin to see a decrease in the impact on user demand.



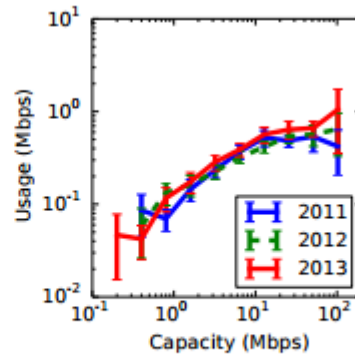
# Longitudinal Trends



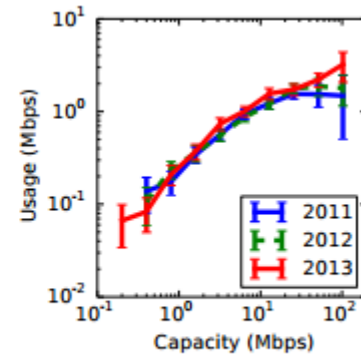
(a) Mean (w/ BT)



(b) 95th %ile (w/ BT)



(c) Mean (no BT)



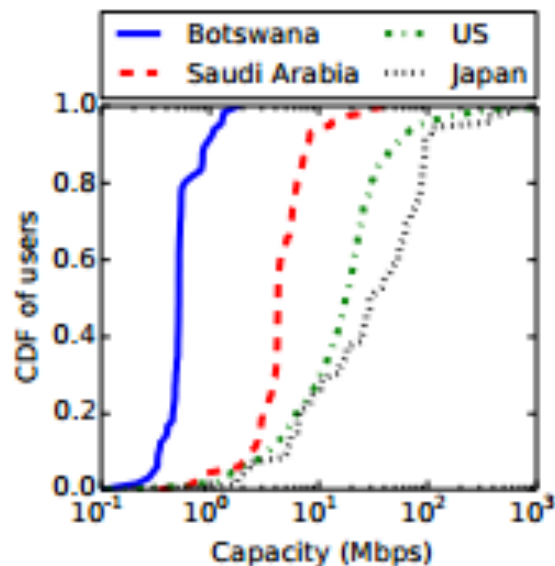
(d) 95th %ile (no BT)

Despite large increases in Internet traffic, demand within a broadband class has remained fairly constant over a two year period.

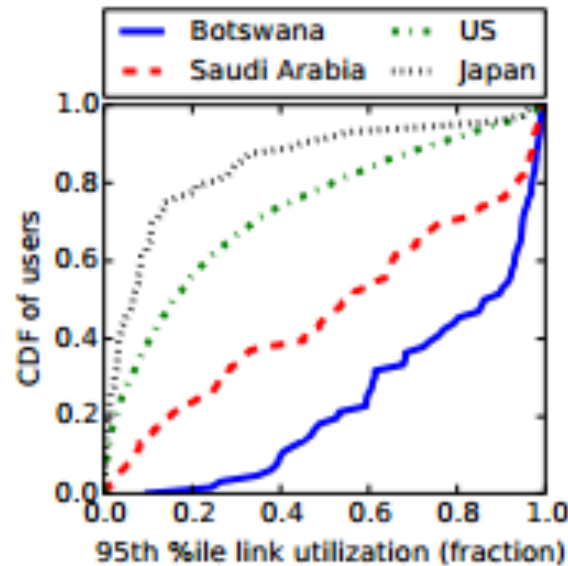
# Price of Broadband Access

Country	Number of users in dataset	Median capacity (Mbps)	Nearest tier (Mbps)	Price in USD (PPP)	Annual GDP per capita (PPP)	Cost of Internet access as percentage of monthly GDP per capita
Botswana	67	0.517	0.512	\$100	\$14,993	8.0%
Saudi Arabia	120	4.21	4	\$79	\$29,114	3.3%
US	3759	17.6	18	\$53	\$49,797	1.3%
Japan	73	29.0	26	\$37	\$34,532	1.3%

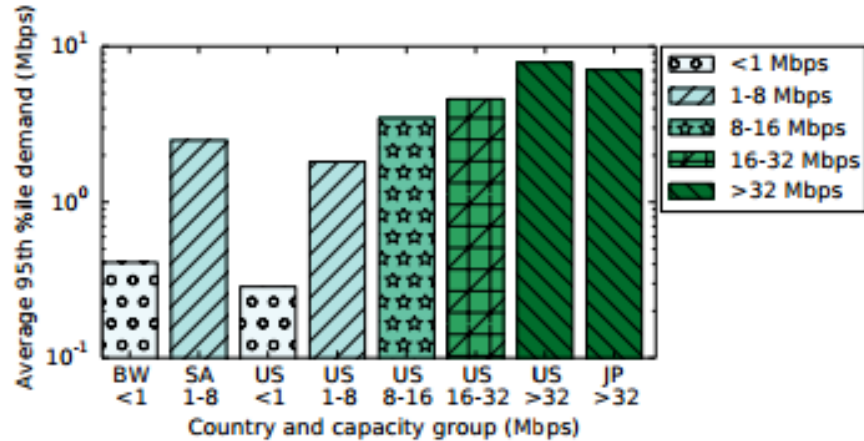
# Cost vs Peak Utilization



(a) Download capacities

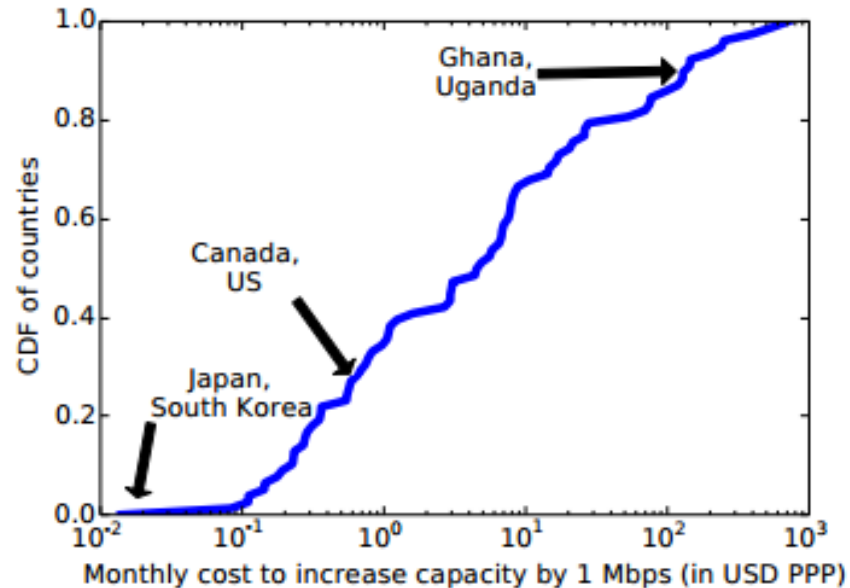


(b) 95th %ile utilization



Compared based off median utilization, more expensive access prices show higher demand. The conclusion being that more expensive costs are preventing people from purchasing higher capacity networks.

# Cost to Upgrade vs User Demand



Control Group	Treatment Group	% $H$ holds	p-value
(\$0, \$0.50]	(\$0.50, \$1.00]	53.8%	0.00717
(\$0.50, \$1.00]	(\$1.00, $\infty$ ]	58.7%	0.0110

(a) Average demand w/ BitTorrent

Control Group	Treatment Group	% $H$ holds	p-value
(\$0, \$0.50]	(\$0.50, \$1.00]	52.2%*	0.0947
(\$0.50, \$1.00]	(\$1.00, $\infty$ ]	56.3%	0.0265

(b) Average demand w/o BitTorrent

$H$  - as the cost to upgrade increases, users are less likely to upgrade and will have higher network demand than users in markets where upgrading is cheaper.

\*result not statistically significant.

# Latency

Does decreased latency result in higher demand?

Comparison of India to US,  $H$  being the hypothesis that higher latency decreases demand.

Control Group	Treatment Group	% $H$ holds	p-value
(512, 2048]	(0, 64]	63.5%	0.00825
(512, 2048]	(64, 128]	63.4%	0.00620
(512, 2048]	(128, 256]	59.4%	0.00766
(512, 2048]	(256, 512]	56.3%	0.0330

Similarly can be shown for packet loss and its effect in India on network demand.

# Further Research

Further research could look into more factors, such as social, political, or weather events and their impact on network usage.

Other areas of interest may be to stop treating all users as one homogenous set and separate them out to further define their network usage habits (gamers, shoppers, students, etc.).



**Questions?**