Traffic Characteristics of Machine to Machine Communication Network
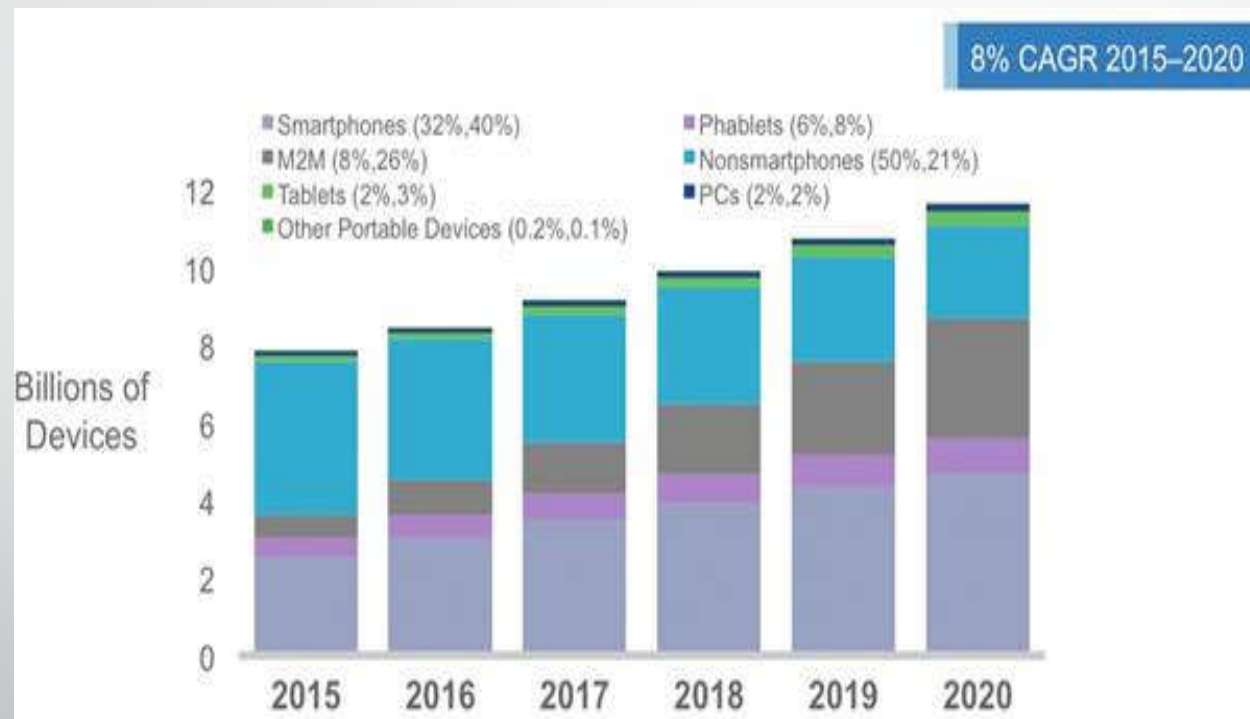
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Machine to Machine (M2M)

Machine to machine refers to direct communication between devices using any communications channel, including wired and wireless. In modern times the communication is often via the Internet of Things (IoT).

~Wikipedia

Cisco Visual Networking Index

Cisco Visual Networking Index

- Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2015–2020

- Globally, M2M connections will grow from 604 million in 2015 to 3.1 billion by 2020, a 38-percent CAGR—a fivefold growth

Paper Review

A First Look At Cellular Machine To Machine Traffic - Large Scale Measurement And Characterization

M.Zubair Shafiq , Lusheng Ji, Alex X. Liu, Jeffrey Pang , Jia Wang

Motivation

- Growth of the smart devices (10 million(2012)-100million(2017))

- Sharing same cellular network with smartphones

- Competition with smartphones for network resources

- Traffic pattern and QoS required for these are different than smartphone

- To be able to answer this question traffic pattern of these devices should be known ?

What are the challenges cellular network operators may face to accommodate traffic from both smartphones and M2M devices?

Key Contribution

- Large Scale Measurement : cellular M2M traffic traces of million devices of 150 hardware models , millions of smartphone traffic from same cellular network

- Aggregate Traffic Volume: Uplink and downlink traffic measurement

- Traffic Volume Time Series : To find the 'peak hour' concept in M2M traffic

- Traffic Session : Active time , session length ,session inter-arrival time

- Device Mobility: M2M devices are less mobile

- Application Usage

- Network Performance: Packet loss ratio and RTT

DATA SET

- Cellular operator in USA (2 G and 3 G)

- Supports GPRS, EDGE,UMTS,HSPA technologies

- Lower Tier : Wireless connection

- Upper Tier : core network interfaces the cellular with Internet

- Each trace is a 5 mins traffic volume

- Session level traffic between cellular devices and internet

- Duration : 1 complete week of August 2010

M2M Device Categorization

- Six categories:

1. Asset Tracking : remotely tracks object. cargo container and other shipment. 18 %

2. Building Security: Door access and security camera. 14%

3. Fleet: Monitor vehicle locations, arrival , departure. 51%

4. Modem: Network connectivity. Generic cellular communication modem. 9%

5. Metering: Remote measurement and monitoring of agriculture , environmental and energy applications.6%

6. Telehealth: Remote healthcare application.2%

Aggregate Traffic Volume

Observations:

1. Traffic volume for smartphones is several order of magnitude higher than M2M traffic.

2. Z > O more uplink traffic
   Z < O more downlink traffic

3. 80% of M2M more is uplink traffic
   80% of smartphone traffic is downlink

4. M2M is more like 'content provider' than 'content consumer'

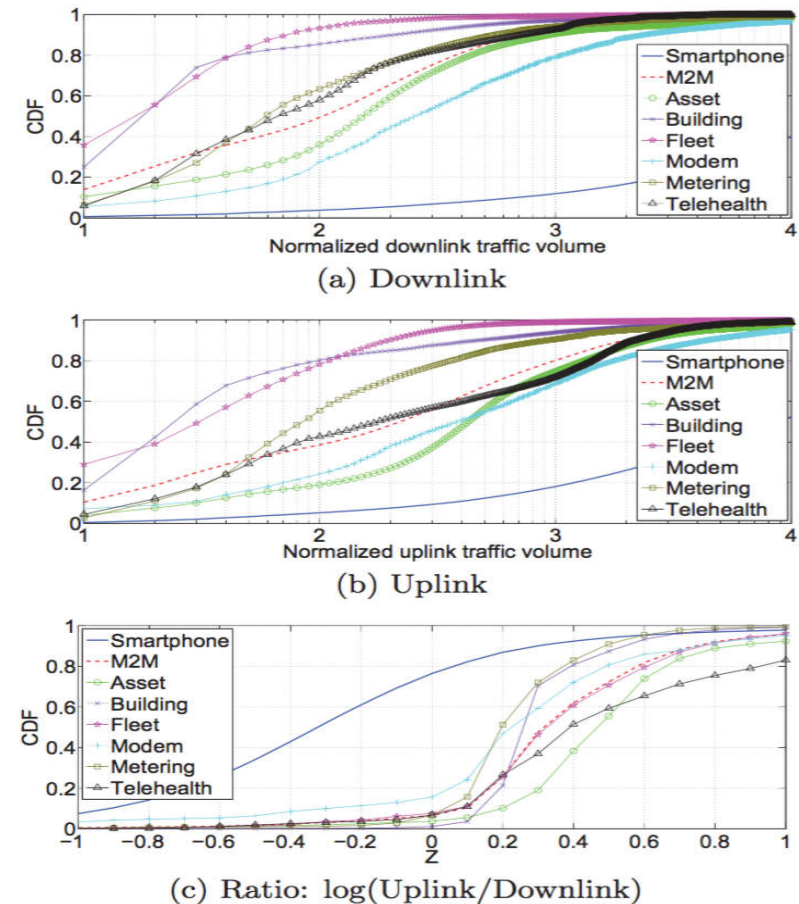5. Building and metering has lowest Z and Telehealth have highest Z.
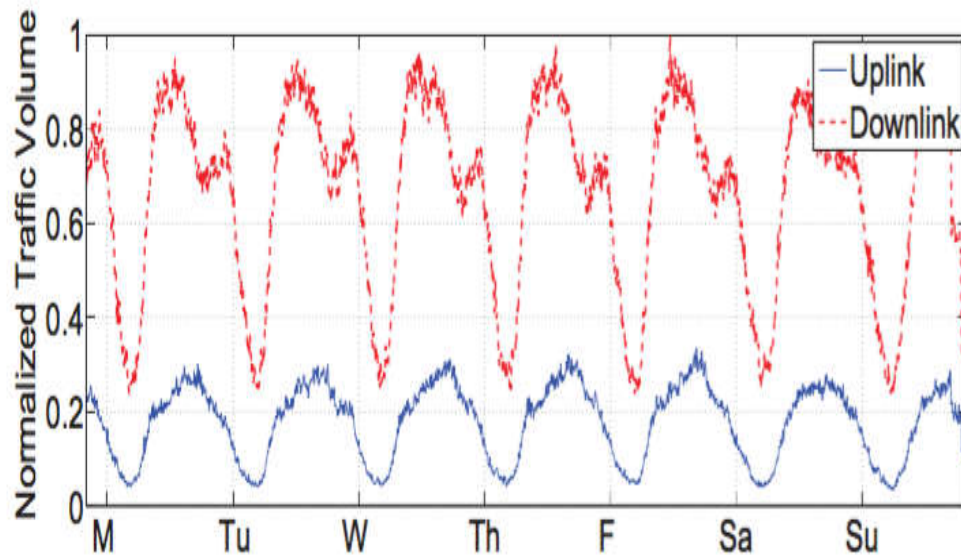
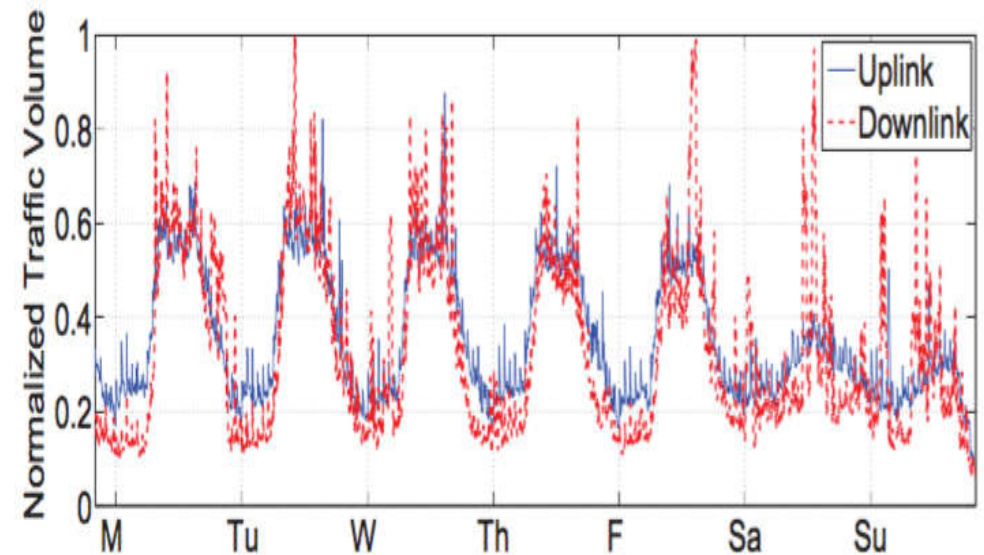

Figure 1: CDFs of aggregate downlink and uplink traffic volume.

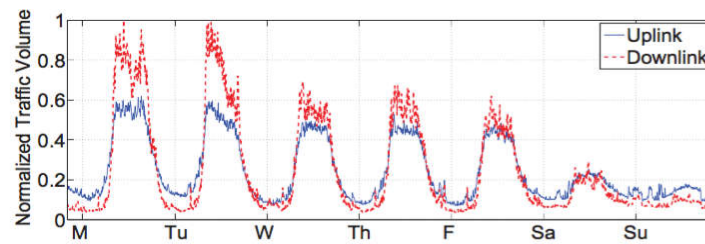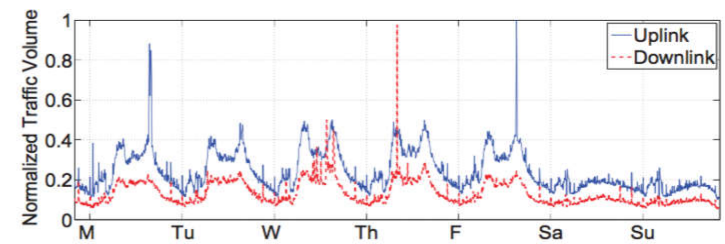# Traffic Volume time Series(Temporal Dynamics)

(a) Smartphone

(b) M2M

Traffic Volume time Series(Temporal Dynamics)

- 1. volume of downlink traffic dominates for smartphone; fairly equal in M2M

- 2.Smartphone traffic time series are wider(starting in the morning ending to midnight)

- 3. M2M traffic time series are narrower, ending by evening time.

- 4. Significant reduction in weekends for M2M.

- Smartphone traffic pattern related to human 'waking' hours.

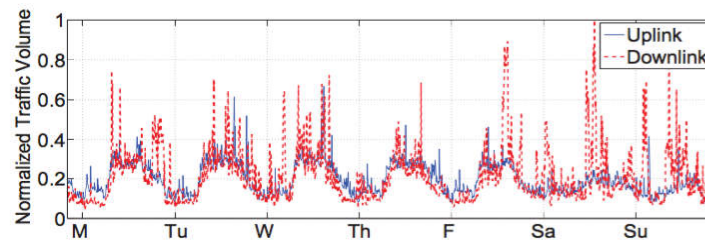- M2M device traffic pattern related to human 'working' hours.
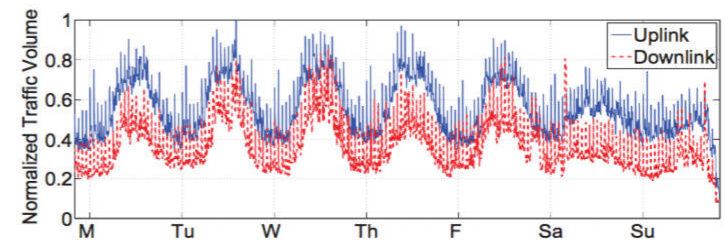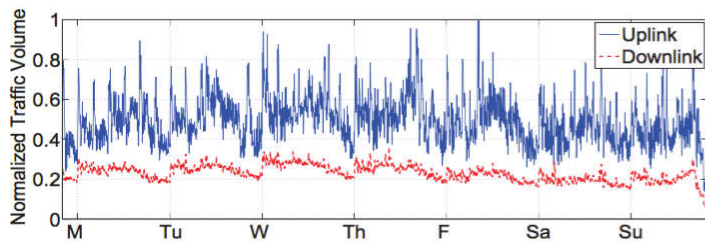
Traffic Volume time Series(Temporal Dynamics)

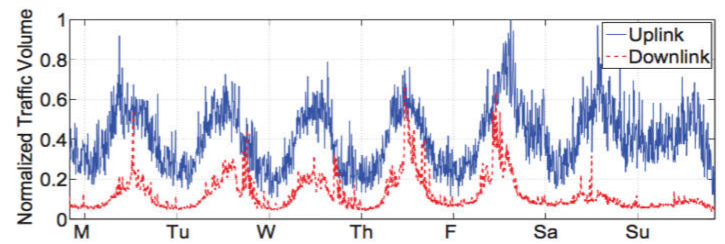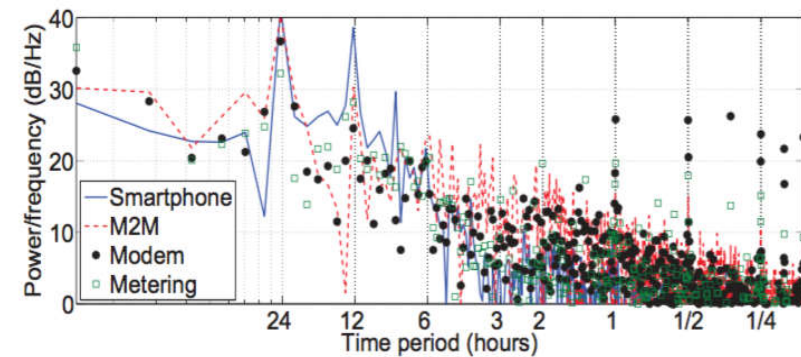Figure 2: Downlink and uplink traffic volume time series.

Traffic Volume time Series(Temporal Dynamics)

Observation :

1. Repetitive spikes in the time series.

2. X-axis in logarithm scale

3. Y-axis power in DB

4. Distinct spikes corresponding multiple time period : 1 hour, 30 minutes,15 minutes

5. Time driven nature of M2M

6.Disruptive congestion due to sub-hour synchronized traffic peaks

(a) Downlink
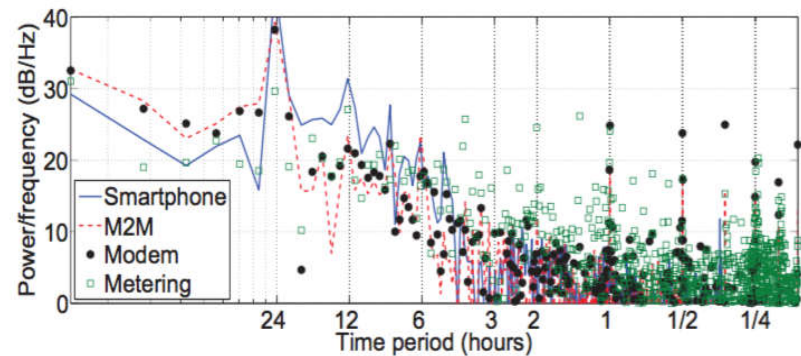
(b) Uplink

Figure 3: Periodograms containing power spectral density estimate of traffic volume time series.

Traffic Volume time Series(Temporal Dynamics)

Traffic volume > 0.5 is high volume
Diurnal Coefficient > 0.1 is high Diurnal

$$DI = \frac{1}{|D|} \sum_{\forall d \in D} \frac{V_{max}(d) - V_{min}(d)}{V_{avg}(d)}.$$

Vmax: maximum avg traffic volume
Vmin: minimum traffic volume
Vavg : average traffic volume
d : particular day
D: span of day

(a) Low Volume-Low Diurnality (LV-LD)

(b) Low Volume-High Diurnality (LV-HD)

(c) High Volume-Low Diurnality (HV-LD)
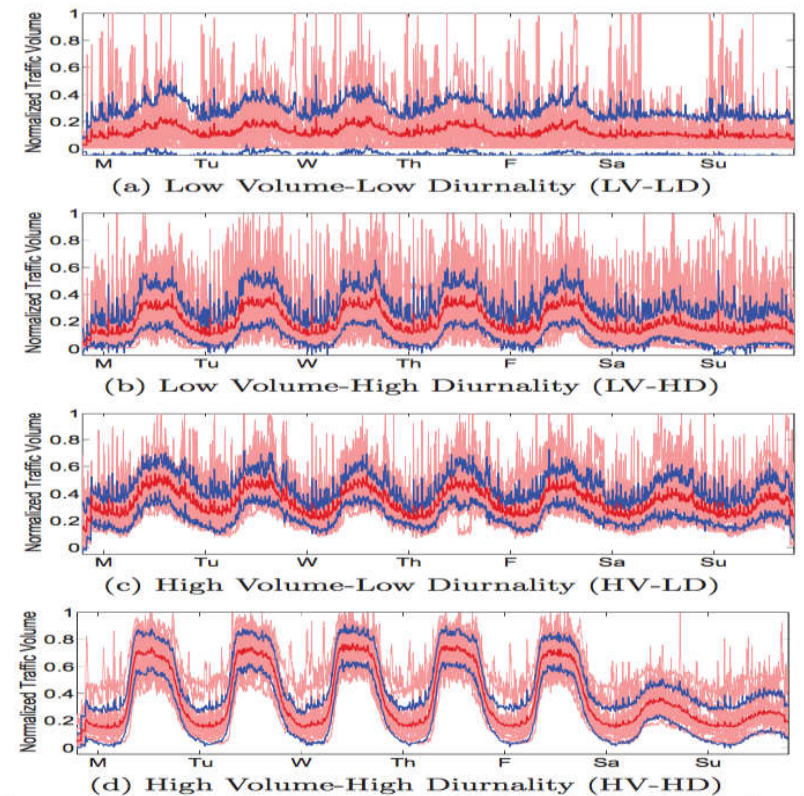
(d) High Volume-High Diurnality (HV-HD)

Figure 5: Cluster centroids identified using device models traffic time series.

Traffic Volume time Series(Temporal Dynamics)

Table 1: Composition of device model clusters.

	LV-LD %	LV-HD %	HV-LD %	HV-HD %
Asset	13.1	16.1	23.5	**33.3**
Building	13.1	**19.3**	11.7	0.0
Fleet	26.2	29.2	5.9	**61.2**
Modem	34.5	25.8	**47.1**	5.5
Metering	**13.1**	3.2	5.9	0.0
Telehealth	0.0	**6.4**	5.9	0.0

Session analysis

- This is valuable for network operator because device active time corresponds more to radio resource usage than aggregate traffic

- M2M service provider better design their devices for battery management

Session Analysis

- Defining a session : a run of flow arrivals in consecutive time bins. Time bins are of 5 mins duration.

- F_t denote absent or presence of flow arrival; binary

- Session is denoted by $S_{\{t_x(i), t_y(i)\}}:$

- t_x is time of first flow arrival and t_y is the time for last flow arrival

- <u>Active time :</u> Total amount of time when the device has traffic

$$T_{active} = \sum_{\forall t \in T} F_t \text{ (counts)} = \sum_{\forall t \in T} F_t * |\Delta| \text{ (time units)}.$$

Session Analysis

- Average Session Length :

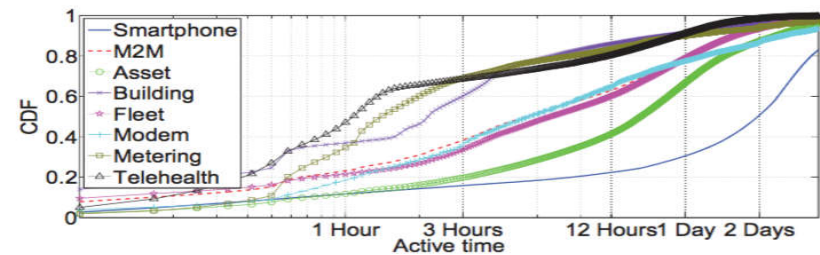$$L_{avg} = \sum_{i=1}^{n} \frac{t_y(i) - t_x(i) + 1}{n}.$$

- Average Session Inter-arrival:

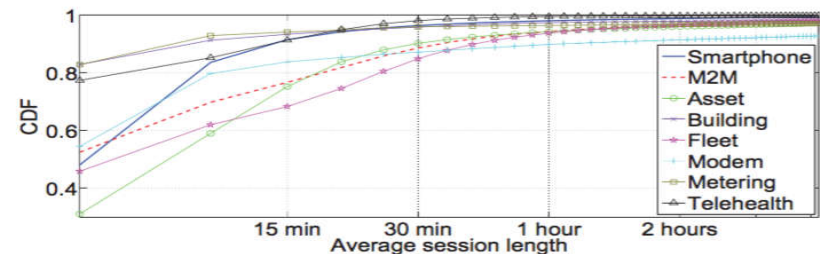$$T_{avg} = \sum_{i=1}^{n-1} \frac{t_x(i+1) - t_y(i)}{n-1}.$$
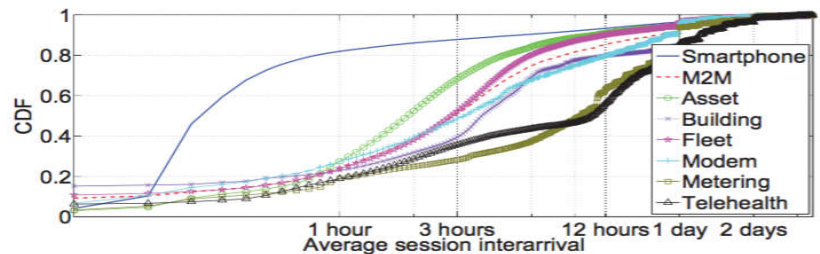
Session Analysis

Observation :

1. Smartphone traffic have higher active Time than M2M device traffic

2. Telehealth and metering has smallest active and session time.

2. Smartphones have smaller session lengths compare to asset tracking and fleet

3. Smartphone traffic has smaller session inter arrival time

Figure 7: CDFs of active time, average session length, and session inter-arrival.

Mobility

Observation :

- Cell identifiers are used to count the number of unique cells a device is involved with to parameterize its mobility.

- It shows smartphones are usually more mobile than M2M except asset tracking. Because they are connected to vehicles.

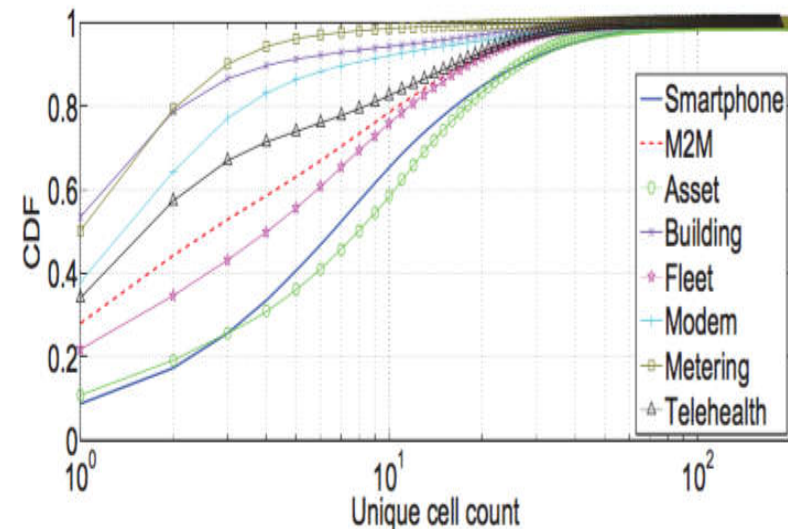- Building security and metering are least mobile among all.
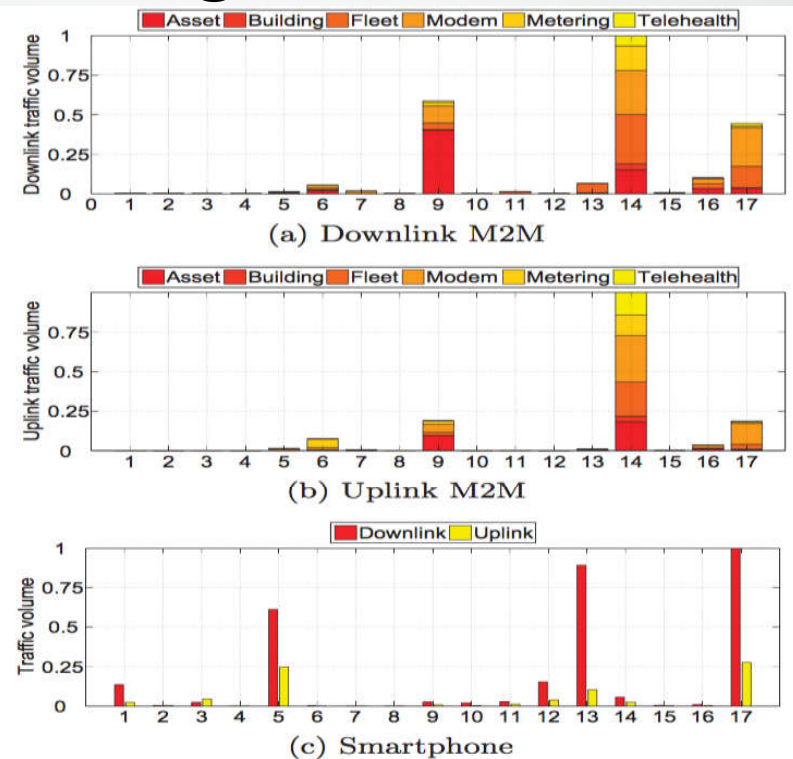

Figure 8: CDFs of unique cells for smartphone and M2M categories.

Application Usage

Observations :

1. Traffic of M2M mostly falls into unknown or miscellaneous realms

2. M2M uses non standard application protocols

3. Smartphone traffic mostly are from web, streaming and email

Figure 11: Traffic application distributions of M2M device categories and smartphone. The application indices along x-axis are: (1) appstore, (2) jabber, (3) mms, (4) navigation, (5) email, (6) ftp, (7) gaming, (8) im, (9) miscellaneous, (10) optimization, (11) p2p, (12) apps, (13) streaming, (14) unknown, (15) voip, (16) vpn, and (17) web.

Network Performance

Observation :
1. M2M devices experiences more delay due
to using external servers

1. Telehealth experiences smaller RTT as
Telehealth and smartphones use 3 G
Modems in contrast with others using
2G modems

3. Telehealth and smartphone experiences
Lesser packet loss due to 3 G modem

4. Building security devices face higher
packet loss for being indoor where signal
quality is poor.
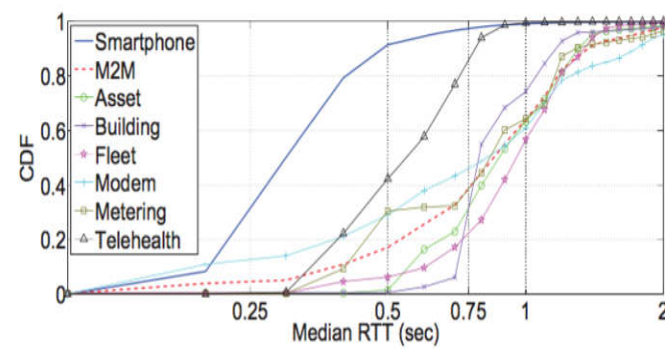
(a) Round trip time
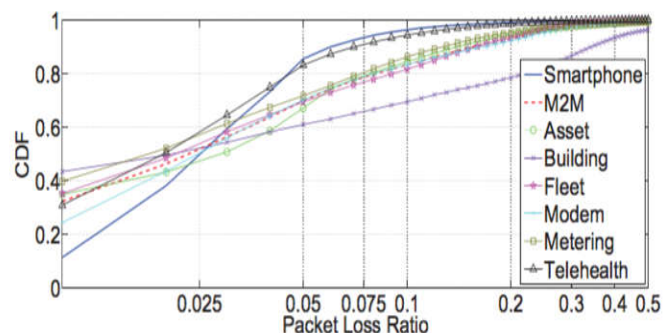
(b) Packet loss ratio

Figure 12: CDFs of round trip time and packet loss ratio.

Conclusion (in comparison with smartphone traffic)

- Average traffic volume is lower than smartphone

- Traffic volume respect to different day of a week depends on human 'wake' time

- Traffic volume peak frequency is synchronous in 1hour to 15 min period of time

- Active time is lower , session length can be high and inter arrival of session time is higher

- Less mobile

- Network performance is lower in terms of packet loss and RTT