Enabling Multi-device Collaborations Using Distributed Mobile Multi-path

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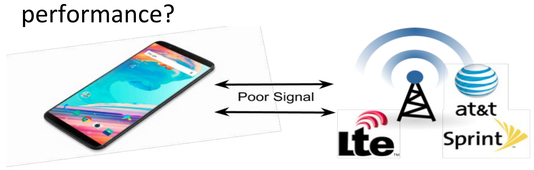
1. Problem Statement

On the one hand, nowadays' **LTE service fluctuates a lot** due to locations and time variations which lead to bad user **QoE**. On the other hand, many high-end devices are idle for the most time, and their active time is not highly correlated. How can we achieve better **QoE** given limited LTE performance?



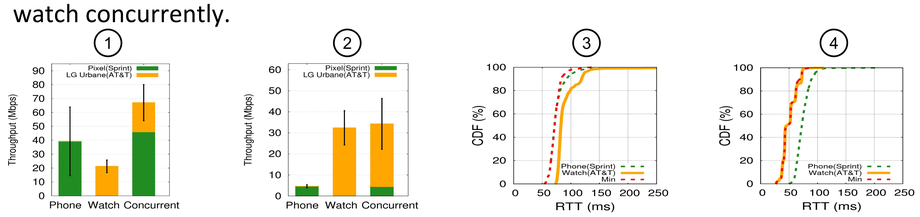
Smartphones are oftentime in the idle state, i.e., no active network traffic.

US adults will spend an average of 3 hours, 35 minutes per day on mobile devices in 2018[1]

[1] Mobile Time Spent 2018 https://www.emarketer.com/content/mobile-time-spent-2018

2. Motivation & Preliminary Experiments

People routinely carry more than one smart devices like **smartphones** and **smartwatches**. Oftentimes, there will be available devices within a group of users. Intuitively, a user can gain more bandwidth with multiple devices. We ran throughput (file download from a server) and latency (ping www.google.com) using different device sets: 1) phone only; 2) watch only; 3) phone and watch concurrently.



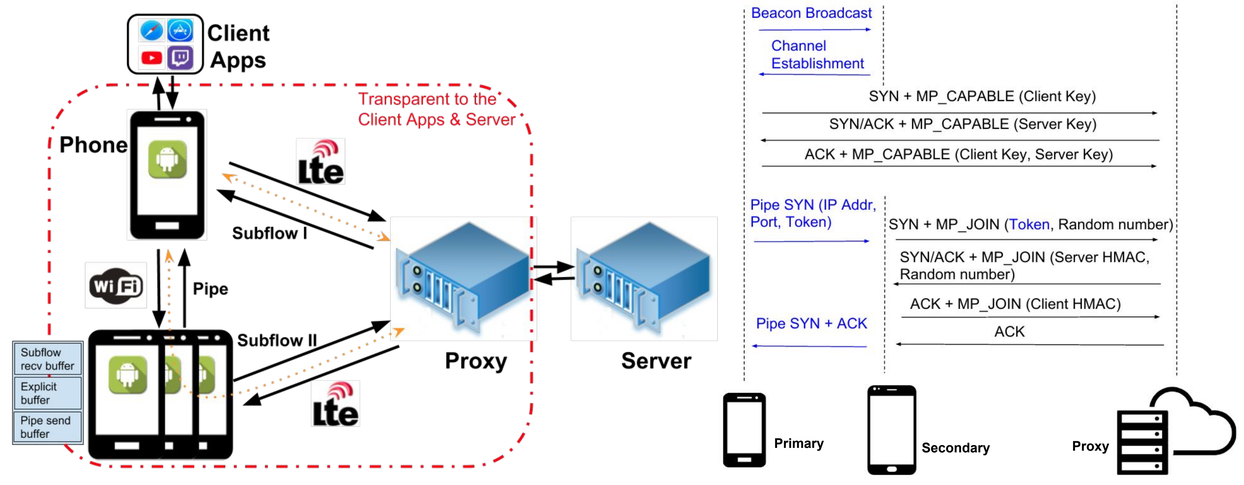
LTE throughput
① residence
② office

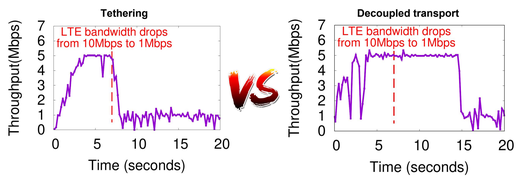
LTE latency
③ residence
④ office

As the figures show, neither of the carriers can consistently outperform the other at all places. **The throughput of the LG watch at office far exceeds that of the Pixel phone, which demonstrates that the smartwatch hardware is not a bottleneck**.

3. Our Solution: DMM

We propose **DMM**, a transport-layer cross-device connection sharing scheme that allows multiple mobile devices to **share each other's network resources**. DMM extends MPTCP, the state-of-the-art multipath solution. By introducing a new primitive called **pipe**, DMM provides a flexible layer-4 channel to bridge multiple mobile devices and facilitate different transport-layer enhancements and policies.





Tethering blindly forwards packets at Layer 3, **hindering various policies and transport layer enhancements over the pipe**.
Instead, we propose **explicit buffering** on the secondary devices to fully absorb the fluctuation of the LTE services, thus maintaining an overall stable performance and low energy consumption.

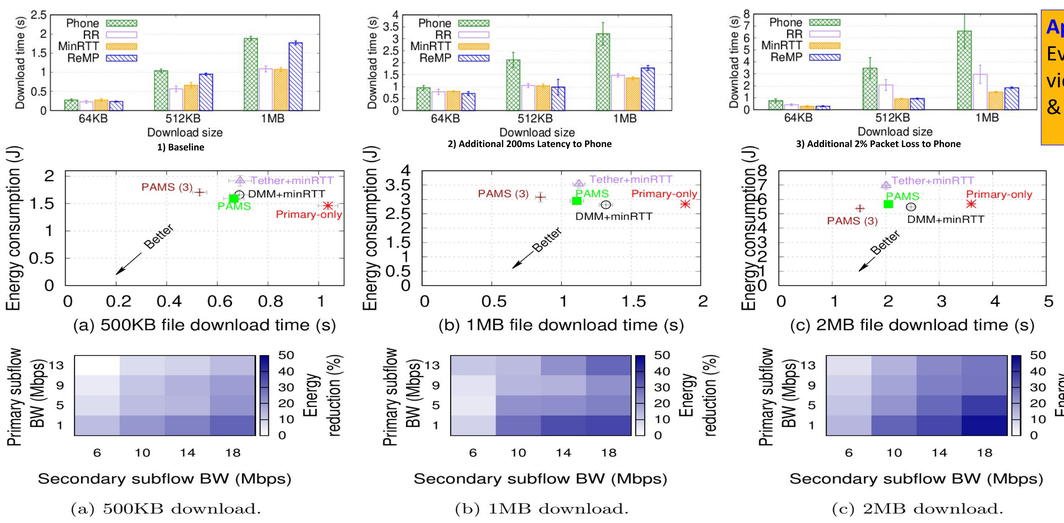
4. Evaluations

We firstly port existing MPTCP schedulers into DMM design and evaluate our system based on them. We then present a Pipe-Aware Multipath Scheduler (PAMS) to enhance our system further. We comprehensively evaluated DMM on the following 4 aspects.

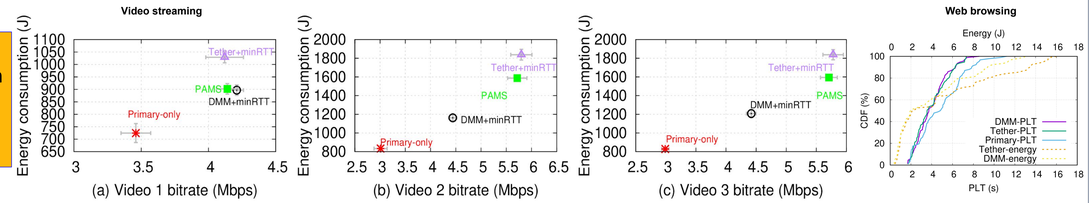
Basic Exp.
Port different schedulers into DMM system to see enhancement

Basic Exp. +
Compare tetheri -ng with DMM w/ & w/o PAMS in bulk download

Energy Exp.
Evaluate under which situations DMM will benefit for energy saving.



Application Exp.
Evaluate DMM in video streaming & web browsing



5. Conclusion

Based on the evaluation, DMM achieves good enhancement of networking performance.

- Basic functionalities are implemented successfully.
- DMM can achieve better energy savings, higher QoE, and more than 2 devices collaborations compared to pure tethering approach.
- For some applications like web browsing, DMM has limited performance improvement.

6. Future Work

- Consider Multi-user situations to make our system more general as a distributed system.
- Design a higher-level scheduling algorithm to determine the helpers and helpees.
- Evaluate DMM on novel Apps like VR, and conduct user studies.