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Review of the PhD thesis titled "Improving Transparency and End-User Control in Mobile Networks" submitted by Ashwin RAO.

Ashwin's thesis presents a body of work that tackles an important and hard challenge in the current mobile ecosystem namely, the *lack of transparency and the resulting loss of end user control* in the ecosystem. The problem arises because the different players in the ecosystem, such as mobile OS providers, app designers, mobile ISPs, mobile content providers, have their own vested interests and conceal their operational details. As a result, end users understand very little about how or what information is being exchanged between the key players. Worse, they can do little to control the information exchanged.

Ashwin's thesis contributions go a long-way towards addressing this situation. First, he proposes a platform, called *Meddle,* which can be used to monitor and manipulate all mobile Internet traffic from a user's devices. Meddle's design is simple yet ingenious – it combines two well-known technologies, VPNs and middleboxes, in an intelligent fashion to enable mobile Internet traffic, including SSL traffic, to be intercepted, examined, and modified, outside the mobile devices that are typically resource constrained. Ashwin's thesis also reports on his experiences implementing and deploying of Meddle in the real world. Implementing and deploying a system like Meddle is a non-trivial task – few research systems that are proposed are ever deployed or used in practice and it is very impressive that Ashwin's has deployed and evaluated his system with over a hundred users.

Second, Ashwin's thesis demonstrates the utility of Meddle by using it to analyze whether mobile applications and services are leaking personally identifiable information (PII) from the mobile device. Leaking PII poses a serious privacy threat and Ashwin's work shows how meddle could be used to investigate potential privacy leaks. What is particularly impressive here is that Meddle's design enables it to analyze SSL traffic as well. Using signatures of PII leaks generated from controlled experiments, Ashwin's thesis identifies PII leaks in the real world, which is an important contribution in its own right. Further, he also shows how Meddle could be used to block PII leaks. Thus, Meddle not only addresses the lack of transparency, but also restores user control over mobile data traffic.

The above contributions, by themselves, might have been sufficient for a good thesis. But, Ashwin's thesis goes further than that. He also leverages Meddle to conduct a study of mobile video (YouTube) traffic, which is increasingly accounting for a lion's share of all mobile traffic. In particular, he studies the network characteristics of YouTube traffic and makes several interesting observations. He finds significant differences between video traffic generated by (i) desktop and

mobile devices, (ii) the different types of browsers and containers over time, and (iii) the devices based on networks (WiFi vs. cellular) being used. The findings illustrate the tremendous amount of insight one could gain into the workings of mobile applications over mobile networks. Such transparency is important to the design of better mobile networks, OS, and apps in the future.

What makes Ashwin's thesis particularly compelling is that the contributions span from system design, implementation, and deployment to data gathering and analysis. It is not often that one encounters a thesis that is strong both on system design and data analysis fronts.

Summary:

In summary, Ashwin's PhD thesis makes significant contribution towards an open problem: bringing transparency and user control to mobile networks. It leverages a wide range of measurement, analysis, and system design techniques to tackle difficult challenges. For these reasons, I strongly recommend that the thesis be accepted in its current form and I believe it deserves to be defended.

Sincerely,

Krishna P. Gummadi