Fighting packet storms in mobile networks with information-centrism

Vaggelis G. Douros, Nikos Fotiou, George C. Polyzos
Mobile Multimedia Laboratory, Department of Informatics
School of Information Sciences and Technology
Athens University of Economics and Business
Patision 76, 104 34, Athens, Greece
E-mail:{douros, fotiou, polyzos}@aueb.gr

***Abstract*—Mobile application development for smartphones is a trend in the telecommunications industry. However, their deployment is not seamless since many applications are not "mobile network-friendly." A key problem that frequently arises is an excessive number of signaling messages, known as signaling storms. This leads to very high overhead and a decrease in operator income.**

We focus on this problem and propose an approach that is based on an information-centric networking deployment at the access network. We compute the number of signaling messages and derive the conditions under which our approach leads to fewer messages than the approach that is used in current networks. We also argue about the network and application layer modifications that are needed for the adoption of our method.

I. Introduction and Motivation

The increasing use of smartphones is a key feature of the post-PC era. Nowadays, more than one third of internet users connect to the Internet mostly through a smartphone [1]. A plethora of mobile applications is constantly developed to support the heterogeneous needs of the mobile users. However, both mobile users and mobile operators are not always able to benefit from this trend.

Smartphone users often complain about low quality receiving data services. This is due to the fact that a number of mobile applications are network-unfriendly as many developers seem to underestimate the differences between a mobile network and a traditional fixed network [2]. In a mobile network, bandwidth and battery life are limited, whereas the network connectivity is not always seamless. If/when these constraints are not taken into consideration successfully, various problems may arise. For example, if a smartphone is always connected, then its battery drains in a couple of hours. Prolonging the battery life by constantly making and breaking the data connections increases the signaling load significantly. Optimizations with proprietary software still lead to 10 times higher signaling load than a laptop [2].

These signaling storm problems have a direct impact to the income of the mobile operators since fewer users are able (and willing) to utilize their services. For example, in 2012, NTT Docomo lost almost 30% of his profit after a major outage in its network [3].

The goal of this work is two-fold: (i) we propose how to avoid signaling storm problems in network-unfriendy applications based on the information-centric networking concept (ii) analyzing a simple model, we derive the condition under which our method outperforms the typical exchange of messages in the current Internet.

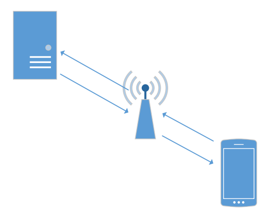

Fig. 1: The topology consists of a Mobile Node (MN), a Base Station (BS) and a server. The arrows correspond to signaling messages that are sent when a MN wants to receive an update from the server.

II. System model and description of our solution

We consider a simple cellular network (Fig. 1) that consists of one Mobile Node (MN) that is associated with its Base Station (BS). The MN owns a smartphone and connects to the Internet communicating directly with the BS. We assume that the MN uses a social network application. This application obtains "friends activity updates" by frequently polling a server. Even if there is no update during a particular interval, an exchange of signaling messages takes place. The MN communicates directly with the BS, whereas the BS communicates with the server in $k \geq 1$ hops in the network layer. In each hop, a message is transferred. Therefore, a total of $2k + 2$ messages are spent (minimum 4 messages, in case that there is a direct communication between the server and the BS).

An Information-Centric Networking (ICN) architecture would have decreased the signaling load. Using ICN, the MN would have generated a permanent "subscription" for updates of friends [4] and any signaling during an idle period would only concern location updates [5]. However, a full-fledged, Internet scale deployment of ICN is not expected to take place in the near future. On the other hand, an overlay, application specific approach, without any support from the underlay architecture would not be beneficiary, since it would require signaling to maintain the overlay network (especially if mobility and disconnections are considered). To this end, we consider a hybrid approach in which ICN is deployed in the access network. At a high level, our approach operates as follows: The MN registers a "subscription" for updates of friends to the BS. The BS periodically polls the server for updates. When there is an available update, the BS checks its records for the current location of the MN and notifies it.

We propose a two step polling protocol: In the 1^{st} step of the protocol, the BS asks the server on behalf of its MN, whether there is an update. The server replies with a 'Yes'/'No'. If the answer is 'No', no further action takes place. If the answer is 'Yes', the 2^{nd} step takes place. During this step, the BS notifies the MN that there is a "match" for its subscription. Then, the standard exchange of messages takes place (MN $\rightarrow$ BS $\rightarrow$ Server and vice versa). In the first step of the protocol, the MN should reveal to the BS a sort-of security token. This token will enable the BS to communicate with the server on behalf of the MN. The form of this token is out of the scope of this paper and it is left as future work.

In each polling period, the number of signaling messages is either $2k$ (when no update is available) or $4k+3$ (when there is at least one available update).

For N polling periods and if we assume that in M out of N the answer is 'Yes', the total number of signaling messages is:

$$M(4k+3) + (N-M)2k \quad (1)$$

This number is smaller than the number of signaling messages of the current model when:

$$M(4k+3) + (N-M)2k < N(2+2k) \Leftrightarrow \quad (2)$$

$$4kM + 3M + 2kN - 2kM - 2N - 2kN < 0 \Leftrightarrow \quad (3)$$

$$M < \frac{2}{2k+3}N \quad (4)$$

We now present some numerical examples based on (4). For a direct communication between the BS and the server ($k = 1$), our scheme reduces the number of signaling messages when the number of periods with updates is smaller than 40% of the total periods. When $k = 9$, *i.e.*, the number of network layer hops to access a twitter server from a mobile phone in Greece (as found by using traceroute), our scheme outperforms the current model when $M < 0.095N$.

A variation of our scheme would further reduce the number of signaling messages. This would be possible with a modification of the 2^{nd} step of the polling protocol. When the server answers 'Yes', it could also send the updated (encrypted) data to the BS. Then, the BS needs just to forward the data to the MN. This variation reduces the number of messages to $2k+1$ when there is an update. Since the number of messages per period is either $2k$ or $2k+1$, with this variation we have either 1 or 2 fewer messages per polling, compared to the existing model.

The improvements mentioned above concern the whole network path from the MN to the server. Nevertheless, packet storms affect the access network. The number of messages *in the access network*, using the existing model for N polling periods is $2N$, whereas in our scheme is $3M$ (or M if the variation discussed previously is applied). Therefore, in a scenario where $M = 0.4N$ our scheme will result in 40% less messages (or 80% if the variation discussed previously is applied) in the access network.

III. Migration Strategy

The realization of our solution requires modifications in the access network, as well as in the applications. We stipulate an ICN protocol in the access network that enables MNs to "subscribe" to events and receive notifications when an event occurs.

In our solution, the access network does not merely forward traffic. BSs now actively participate in the polling protocol. In order for this to be achieved, BSs should be able to understand the considered ICN protocol, accept subscriptions and send notifications when necessary.

Similarly, applications should be built with this asynchronous communication paradigm in mind. The client part of the applications should implement the ICN protocol and subscribe for events. The server part of the application should implement the two step protocol discussed in the previous section.

IV. Conclusions

In this work, we show that a hybrid adoption of the ICN architecture at the access network can be a prominent candidate to reduce the probability for the signaling storm problem that frequently arises in the mobile networks. Even through the usage of a very simple model, it becomes obvious that this approach can reduce both the traffic in the access network and the end-to-end traffic.

In this paper, we considered that the new functionality is implemented in the BSs. As future work, the polling protocol can be assigned to an external entity instead of the BS. This entity could communicate directly with the BSs of the same operator, acting as the mediator between them and the server. Moreover, as long as this entity has a stable network address, overlay ICN can be implemented between this entity and the server and reduce the load. Our immediate steps include the evaluation of our approach using real world data.

V. Acknowledgment

This research has been co-financed by the European Union (European Social FundESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF)Research Funding Program: Aristeia II/I-CAN.

References

[1] "Mobile technology fact sheet," Pew Internet Projects research, http://www.pewinternet.org/fact-sheets/mobile-technology-fact-sheet/, Tech. Rep., 2014.

[2] "Understanding smartphone behavior in the network," Nokia Siemens Networks Smart Labs, Tech. Rep., 2011.

[3] M. Siekkinen, M. A. Hoque, J. K. Nurminen, and M. Aalto, "Streaming over 3g and lte: How to save smartphone energy in radio access network-friendly way," in *Proc. 5th ACM Workshop on Mobile Video*, 2013.

[4] C. Tsilopoulos and G. Xylomenos, "Supporting diverse traffic types in information centric networks," in *Proc. ACM SIGCOMM Workshop on Information-centric networking*, 2011.

[5] N. Fotiou, K. Katsaros, G. C. Polyzos, M. Särelä, D. Trossen, and G. Xylomenos, "Handling mobility in future publish-subscribe information-centric networks," *Springer Telecommunication Systems*, vol. 53, no. 3, pp. 299–314, 2013.