Context-Aware Forwarding in Destination-less OppNets

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Internet of Things (IoT) has emerged as a result of modern devices with enhanced communication and processing capabilities. This in turn, facilitates ubiquitous/pervasive computing where the data from different users in an environment can be processed to identify or classify useful information for real-time applications, such as healthcare, smart grids, logistics, smart homes etc. The challenge here lies in identifying the communication technologies suitable for such vast and massive networks. Initially, wireless infrastructures, such as cellular networks and WLAN, were considered to be sufficient to serve IoT users. However, the lack of spectrum availability has limited the potentials of these technologies to serve IoT users exclusively.

The whole body of research is dedicated to deal with scarcity of spectrum and efficient use of available spectrum by utilizing spectrum gaps and white spaces. Even though this is a valid and promising approach, it is not sufficient to cater to the growing needs for computing and data, which brings us back to the lack of bandwidth again. Hence, the focus has been shifted from mitigating these issues to find other ways to deal with the problem. One such alternative is deviating from infrastructure-based cellular networks for IoT data transmission, and thus emerged Opportunistic Networks (OppNets).

In OppNets, the devices communicate whenever they have an opportunity to communicate. In other words, OppNets are composed of any number of devices (both fixed and mobile) enabled with seamless data exchange methodologies. In contrast to the popular infrastructure networks, OppNets are delay and disruption-tolerant networks without guaranteed deliveries and delays. Nevertheless, they seamlessly provide all the functionalities needed for any IoT-suited service.

Application Areas

Opportunistic Networks are defined as a set of applications and services running on end-user devices that use direct communication opportunities among them in order to exchange information. OppNets have strong potential in the fields of cellular network offloading, communication in challenged areas, censorship circumvention and proximity based applications and vehicular communications. Another common use of OppNets in our everyday life is embedded in uncritical, but essential communications such as chat applications where people usually flood network with latest gigs, gossips, jokes and so on.

Research Question

The OppNet application scenarios are mostly designed in the same way as classical infrastructure-based networks, despite the differences in their operational behavior. For instance, a source generates a message and there is a specific destination that needs it or the source needs the destination to respond. For example, in a disaster scenario, which has been the main motivation for OppNets: a node which is in the location of a disaster and requires help or which has information about the disaster and wants to inform the helpers is the source; a fire brigade, volunteers, evacuation management services are some of the possible destinations. As a result, most of the OppNet protocols are designed to operate for destination-oriented applications even though OppNets are not limited to such application scenarios. OppNets are an effective tool for network-wide data dissemination, which is one of OppNets' major benefits, unfortunately attracting less attention.

The major difference between destination-oriented OppNets and destination-less OppNets lies in the fact that the destination-oriented applications assume that each message has a dedicated destination, being it a single user or a group of users, while the destination-less applications do

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not know this from the beginning – they assume all users might or might not be interested in their data. It remains thus the goal of the data propagation protocols to decide where to deliver them.

Designing a forwarding protocol for highly-scalable destination-less OppNets necessitates the consideration of the following factors: requirements for data propagation in destination-less environments; mode of data dissemination – broadcast or unicast; selection of forwarding data to neighbors in the absence of destination requirements; context information to be used for destination-less applications; reducing the network overhead while intelligently disseminating information to multiple nodes.

In addition, simulations have been the most promising testing environment for such a large network. However, the evaluation scenarios do not come anywhere close to a real-world OppNet environment. As there are no specific standards for OppNets, there are no benchmarks either, as to the valid or relevant evaluation scenarios to test OppNet protocols. Therefore, evaluation scenarios suitable for the protocol operation and application have been considered in the literature so far. However, certain parameters influence on the performance of OppNet protocols in terms of the desired metrics, regardless of the type of applications. Although the current scenarios used for evaluation verify that the protocols work as expected, they are far from estimating if these protocols can be scaled and adopted for real-world use.

The main objective of this doctoral thesis is to design and develop forwarding protocols regarding destination-less applications and to design suitable evaluation scenarios for highly scalable real-world OppNet applications.

Methodology

Simulations will be the main mode of implementation and evaluation of the protocols. More specifically, an opportunistic framework called Opportunistic Protocol Simulator (OPS) based on OMNeT++ will be used as the development environment. After identifying the suitable technology and the mode of transmission, hardware implementations based on Arduinos and Raspberry Pis will be carried out to analyze the protocol functionality in reality. The forwarding protocol for destination-less environments will be developed and evaluated in an iterative manner.

Solution Approaches

Some of the approaches of forwarding protocols for destination-less applications are discussed here.

Broadcasting the data: Most of the protocols from the literature focus on unicasting the data to every neighbor they meet, mainly following the design of destination-oriented applications as in cellular networks. In case of using Bluetooth for message exchanges, the user-devices have to be paired and the message has to be accepted with user's permission. This is not a suitable strategy to disseminate data due to the short contact times exhibited in OppNets with high mobility. However, if the data is sent as broadcast, that would reduce the additional overhead and result in faster data dissemination.

Optimizing the flooding approaches: One of the ways to tailor flooding approaches to meet our needs is to remove the destination restrictions and let the data spread until its expiration time, increasing the overhead. On the other hand, summary vector exchanged in Epidemic Routing can be broadcasted while the data request from interested nodes can be sent as unicast. Furthermore, two nodes do not need complete summary vector exchanges as they can be synchronized with summary vector transmission of one of the nodes.

Deducing environment changes with least overhead: Without explicitly monitoring location updates, changes in the environment need to be identified. Every node should have an in-built mechanism to estimate the changes in the environment and alter their data dissemination accordingly. For this purpose, suitable machine learning methods need to be identified.

Feedback mechanisms and incentives for forwarders: Efficient techniques to acquire data suitable for one's own interest along with willingness to act as a forwarder has to be considered. Incentives for forwarding nodes will be considered as a feature in potential solutions.

Outcome

The outcome will be one or few forwarding protocols for destination-less OppNets. The forwarding protocol will be able to learn and adapt according to the environment such that it achieves effective data dissemination with minimum overhead.