Combining Opportunistic and Information Centric Networks in Real World Applications

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***Abstract*—With the ever increasing number and power of computing devices around us, we envision a world where we are surrounded by information. Opportunistic Networking could play a role in this scenario and we explore approaches to improve Opportunistic Networks by exploiting the new paradigm of Information Centric Networking.**

I. Motivation

Opportunistic Networks have been an active research field since the beginning of this century and many protocol proposals followed the first set of pioneering papers. Nevertheless, the problems introduced by the generally unpredictable and potentially high node mobility and by the frequent possibility of network partitions pose a serious challenge to protocol designers and a limit to the performance, e.g. in term of latency and reliability. This class of networks is also often referred to as *Delay Tolerant Networks* (DTN).

The great majority of the approaches in literature propose an host-to-host model, so when a node initiates a communication, its aim is to specifically reach another well defined host. Several problems and difficulties in DTNs arise due to this design choice and, in many cases, there exist communication models that better suit users' needs. Recent studies show, for instance, that in the Internet the great majority of the users are only interested in retrieving an information, but the physical provider of that information (i.e. the host at the other end of the communication) has little relevance, as long as the information integrity is guaranteed.

That being so, a key element to achieve better performances in many situations could be the introduction of Information Centricity. *Information Centric Networking* (ICN) [1]–[3] is a paradigm that shifts the attention from the host to the data. Nodes are allowed to request pieces of data by mean of unique identifiers and, in principle, any node is allowed to provide the data, even though it is not its original source. Under these conditions, when a node forwards a piece of data, it is convenient, from the network point of view, that it keeps the data in a local cache to satisfy further forthcoming requests. Several ICN architectures have been proposed in recent years, but with a fixed, Internet-like infrastructure in mind.

We think that an Information Centric approach might mitigate or solve some of the problems that affect Opportunistic Networks, allowing for seamless content caching and replication, embedded security, possibility to fetch the data from the closer location and, under certain assumptions, significantly improve performance and usability. Furthermore, ICN seems a perfect match for the store-carry-forward paradigm used in DTN approaches, that closely resembles the content store (cache) adopted by many ICN proposals.

II. Related Work

The problem of routing in opportunistic networks has been extensively studied. Some class of solution, like mobile ad-hoc networking (MANET), assume a relatively low node mobility and the existence at any point in time of a path between any network node. Networks where this assumption fall and partitions can happen have been studied in [4] and the term DTN has been introduced in [5]. Then a long list of protocols followed, including [6] that has been used in our experiments. The common approach is *store-carry-forward*, meaning that a message is kept in the node's cache until a "good" transmission opportunity happens. For an exhaustive list of DTN protocols see [7], [8].

The concept of Information Centric Networking proposes a shift from a location-based approach to an information-based one. The term is generic and several concrete proposals exist, including [1]–[3]. They are mainly aimed at Internet-like networks. Some recent works have studied the possibility to design information centric solutions for opportunistic networks, including [9]–[11].

III. Work Done

Until now, we considered different possibilities, focused both on real world application and on more theoretical studies to improve protocol performances. All the approaches studied so far try to combine ICN and DTN.

A. ICN in Emergency Situations

In [12] we studied the possibility of establishing a delay tolerant communication system in the aftermath of a severe natural disaster, exploiting only the mobility of the people and of emergency vehicles, without requiring any pre-existent infrastructure. We propose *Delay-tolerant ICN for Disaster-management (DID)*, a protocol based on controlled information dissemination, that prioritizes messages and takes into consideration nodes' encounter history and direction.

Emergency and natural disaster are a prominent example of scenarios where a communication infrastructure could be vital. In the aftermath of catastrophic events, including earthquakes, tsunami, terroristic attacks, the standard communication infrastructure (landlines, mobile phones, Internet, etc.) resulted often so severely damaged that even basic services were not working. In the case of Japanese earthquake in 2011, infrastructural

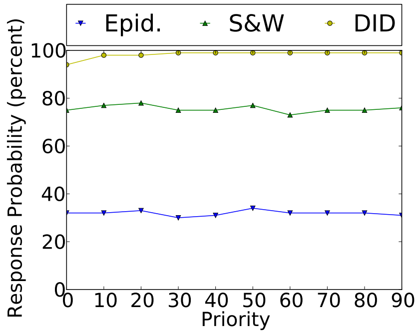

Fig. 1: Ratio of satisfied data requests. Results are obtained using our protocol (DID), Spray and Wait(S&W) and Epidemic.

damages and congestion resulted in up to 95% of voice calls, including emergency ones, denied for a long time [13].

The main motivation of our work is to build a delay tolerant network that can stand in for the damaged infrastructure and allow at least basic communication among citizens and between citizens and authorities or first responders. Several message types are envisioned, including help requests, private communication (e.g. to check the status of a relative) and warnings or information dissemination (e.g. shelter locations, medicine availability, migration plans, etc.).

The results in [12] are based on a simulated scenario where nodes move in an urban area with a random waypoint mobility model. Although a real-world disaster situation could probably be more complex, this setup gives us precious insights.

In Figure 1 DID's performance in term of response probability is compared with classic approaches. Encounter history, computed only for certain types of nodes (communities of more nodes, static nodes, etc.), gives our protocol a clear advantage. The work only represents a starting point: a more in-depth study on data naming, data retrieving, caching, data prioritization could be made, each being an interesting and relevant element that directly affects the functioning of the proposed protocol and can greatly enhance its performance. Furthermore, many other scenarios can be studied, both in simulations and implementing real-world prototypes. It would be interesting to investigate the feasibility of a delay tolerant communication system based on Android phones, exploiting the recently added WiFi-Direct technologies that allows phone-to-phone direct communication.

B. *Combining multiple protocols*

Another idea we are pursuing is that of combining multiple routing protocols, letting each node dynamically decide which one to use based on local conditions and message type.

This idea stems from the observation that many delay tolerant protocol already exist in literature, but no one is clearly the best. Each presents advantages and drawbacks and its performance highly depends on the scenario conditions. Due to diverse network and device conditions in opportunistic networks (e.g., battery level, base-station status, node mobility and density) the routing and replication protocols need to be able to adapt accordingly. If nodes were able to correctly determine which protocol to use, there could be a great performance benefit. We have not published results yet, but we are running experiments and simulations with positive expectations.

IV. Conclusion and Future Work

There are many situations in which a fixed infrastructure lacks or is temporary unavailable, or in which a distributed, decentralized approach is to be preferred. We think that Opportunistic Networking represents an ideal solution for these scenarios, thanks to its easy-to-deploy, resilient, distributed nature. We envision the introduction of ICN as a key element to improve the performances of the approaches proposed in literature. Furthermore, we will study the possibility to exploit several protocols simultaneously, deciding which protocol to use on a per-message basis in a dynamic, distributed manner.

By careful analyzing specific situations and looking at the existing solutions, we hope to propose enhancements and advance the state of the art. Among the others, we can think of Opportunistic Networks in the context of VANETs, IoT, Pervasive Computing, Emergency situations, Mobile Social Networks and communications in Remote/Rural areas.

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