Opportunistic Routing in Delay Tolerant Network with Different Routing Algorithm

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Abstract: ***Present new mechanisms for modelling multiple interfaces on a node, support for interference-limited links and a frame-work for modelling complex applications running on the nodes. Furthermore, provide an overview of concrete use cases where the simulator has been successfully exploited to study a variety of aspects related to opportunistic, message-based communications. Node movement is implemented by movement models. These are either synthetic models or existing movement traces. Connectivity between the nodes is based on their location, communication range and the bit-rate. The routing function is implemented by routing modules that decide which messages to forward over existing contacts. Finally, the messages themselves are generated either through event generators that generate random traffic between the nodes, or through applications that generate traffic based on application interactions. The main functions of the simulator are the modelling of node movement, inter-node contacts using various interfaces, routing, message handling and application interactions. Result collection and analysis are done through visualization, reports and post-processing tools.***

Keywords: Opportunistic Routing Algorithm, WIFI Model

1. Introduction

Simulations play an important role in analyzing the behaviour of DTN routing and application protocols. With typically sparsely distributed nodes, DTN simulations abstract from the details of the wireless link characteristics and simply assume that two nodes can communicate when they are in range of one another. This allows focusing on the evaluation of the DTN protocols an approach we follow in this paper. Instead of fully modelling the lower layers we make simplifying assumptions about the data rates, the radio ranges, and thus the resulting transfer volumes.

In sparse node populations, the space-time paths, which are exploited by the store-carry-forward communications, are composed of the encounters between the nodes. The frequency, duration, and other characteristics of these encounters are largely dependent on the underlying mobility patterns. Evaluations of DTN protocols have used a large variety of

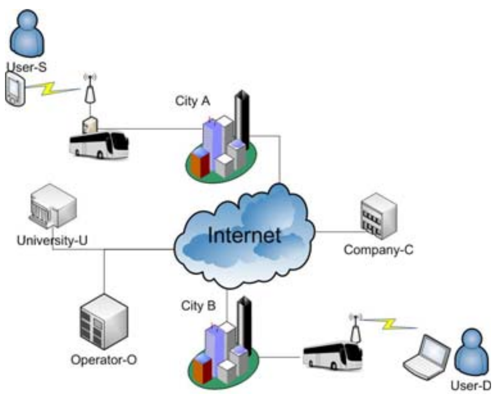

Figure 1: Sample DTN model

Synthetic mobility models as well as real-world mobility traces. While synthetically generated node mobility allows for fine tuning in many respects, this usually covers only limited mobility characteristics. In contrast, real-world traces often have only coarse temporal (e.g., scanning intervals in the order of several minutes) or spatial resolution (e.g., location determined from WLAN access point attachment) and coverage (e.g., only covering a campus area) and may exhibit biases due to the user group chosen for sampling.

All these approaches may provide complementary data points when assessing the performance of DTN protocols. What is important is that protocols are evaluated under different settings and that these settings can be fine tuned to match the intended application scenario(s) as closely as possible.

2. Problem Statement

This can be formulated as an optimization problem that maximizes total network throughput subject to information conservation constraints, opportunistic constraints, and interference constraints. Interestingly, topology control can be cast as a routing problem and can be optimized in the same framework. Note that since our optimization problem is non convex, existing techniques developed for distributed convex optimization are not directly applicable.

3. Related Works

DTNRG architecture [5] proposes a bundle layer as an overlay to bridge different (inter)networks. Nodes communicate via asynchronous messages of arbitrary size that are exchanged using the store-carry-and-forward paradigm. Messages have a finite TTL and are discarded when the TTL expires. They may also get dropped by a node due to congestion, yielding a best-effort service. Application protocols need to tolerate the delays resulting from the challenged environment and the risk that messages are not delivered in time or not at all. Typical performance metrics for evaluating DTN protocol performance are hence message delivery probability and latency.

Numerous routing and forwarding schemes have been proposed over the past years (refer to [5] and [3] for overviews). Different mechanisms are usually applied depending on whether the network is primarily of mobile adhoc nature (e.g., mobile devices carried by humans) or is based upon a (fixed or mobile) infrastructure (e.g., space networks, bus networks). Obviously, mixed networks exist as well, for example, with mobile users supported by infrastructure nodes.

The primary difference between various DTN routing protocols is the amount of information they have available to make forwarding decisions [3]. Ad-hoc DTNs usually apply variants of reactive protocols. Flooding protocols such as epidemic routing [3] do not use any information. Predictive protocols use past encounters of nodes to predict their future suitability to deliver messages to a certain target whereas other protocols also exploit further (explicitly configured) schedule and context information per node [2]. Furthermore, they differ in their replication strategies, i.e., how many copies of a message they create which, in turn, has a direct impact on the load incurred on the network. Opportunity occurs between two nodes. Finally, queue management strategies define when and which messages are deleted, e.g., if congestion occurs.

4. Proposed System

Focus on communication performance in delay-tolerant ad-hoc networks comprising mobile nodes. Delay-tolerant Networking [1] is increasingly applied to enable communication in challenging networking environments, including sparse sensor nets and opportunistic mobile ad-hoc networks. The main functions of the simulator are the modelling of node movement, inter-node contacts using various interfaces, routing, message handling and application interactions. Result collection and analysis are done through visualization, reports and post-processing tools. The elements and their interactions are shown in Figure 2.

Node movement is implemented by movement models. These are either synthetic models or existing movement traces. Connectivity between the nodes is based on their location, communication range and the bit-rate. The routing function is implemented by routing modules that decide which messages to forward over existing contacts. Finally, the messages themselves are generated either through event generators that generate random traffic between the nodes, or through applications that generate traffic based on application interactions. The messages are always unicast, having a single source and destination host inside the simulation world.

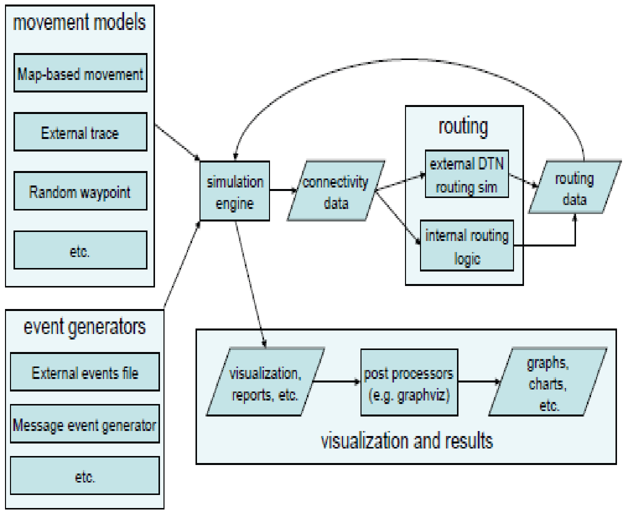

Figure 2: Overview of the simulation environment

Simulation results are collected primarily through reports generated by report modules during the simulation run. Report modules receive events (e.g., message or connectivity events) from the simulation engine and generate results based on them. The results generated may be logs of events that are then further processed by the external post-processing tools, or they may be aggregate statistics calculated in the simulator. Secondarily, the graphical user interface (GUI) displays a visualization of the simulation state showing the locations, active contacts and messages carried by the nodes.

4.1 Network Model

The basic agents in the simulator are called nodes. A node models a mobile endpoint capable of acting as a store-carry-forward router (e.g., a pedestrian, car or tram with the required hardware). Simulation scenarios are built from groups of nodes in a simulation world. Each group is configured with different capabilities. Each node has a set of basic capabilities that are modelled.

These are radio interfaces, persistent storage, and movement, and energy consumption, message routing and application interactions. Node capabilities such as persistent storage that involve only simple modelling are configured through parameterization (e.g., peer scanning interval and storage capacity). More complex capabilities such as movement, routing and network interfaces are configured through specialized modules that implement a particular behaviour for the capability (e.g., different mobility models or interference-limited radio interfaces).

The node energy consumption model is based on an energy budget approach. Each node is given an energy budget which is spent by energy consuming activities such as transmission or scanning and can be filled by charging in certain locations (e.g., at home). An inquiry mechanism allows other modules to obtain energy level readings and adjust their actions (e.g., scanning frequency as, forwarding activity, or transmission power) accordingly.

4.2 Mobility Model

Node movement capabilities are implemented through mobility models. Mobility models define the algorithms and rules that generate the node movement paths. Three types of synthetic movement models are included: 1) random movement, 2) map-constrained random movement, and 3) human behaviour based movement.

Framework for creating movement models as well as interfaces for loading external movement data. Implementations of popular Random Walk (RW) and Random Waypoint (RWP) are included. While these models are popular due to their simplicity, they have various known shortcomings. It is also possible to completely omit mobility modeling and construct topologies based on static nodes.

To better model real-world mobility, map-based mobility constrains node movement to predefined paths and routes derived from real map data. Further realism is added by the Working Day Movement (WDM) model that attempts to model typical human movement patters during working weeks.

4.2.1 Map-Based Mobility

Map-based movement models constrain the node movement to paths defined in map data. The simulator includes three map-based movement models: 1) Random Map-Based Movement (MBM), 2) Shortest Path Map-Based Movement (SPMBM), and 3) Routed Map-Based Movement (RMBM). Furthermore, the release contains map data of the Helsinki downtown area (roads and pedestrian walkways) that the map-based movement models can use. However, the movement models understand arbitrary map data defined in (a subset of) Well Known Text (WKT). Such data is typically converted from real world map data or created manually using Geographic Information System (GIS) programs.

4.2.2 Working Day Movement Model

The WDM model brings more reality to the node movement by modelling three major activities typically performed by humans during a working week: 1) sleeping at home, 2) working at the office, and 3) going out with friends in the evening. These three activities are divided into corresponding sub-models between which the simulated nodes transition depending on the time of the day. Beyond the activities themselves, the WDM model includes three different transport models. The nodes can move alone or in groups by walking, driving or riding a bus. The ability to move alone or in groups at different speeds increases the heterogeneity of movement which has impact on the performance of, e.g., routing protocols.

Finally, WDM introduces communities and social relationships which are not captured by simpler models such as RWP. The communities are composed from nodes which work in the same office, spend time in the same evening activity spots or live together.

4.3 Routing Message

Spray-and-Wait is an n-copy routing protocol that limits the number of message copies created to a configurable maximum and distributes (“sprays”) these copies to contacts until the number of copies is exhausted. Both variants of Spray-and-Wait suggested by its authors are included: in normal mode, a node gives one copy to a contact; in binary mode half of the copies are forwarded. Once only a single copy is left, it is forwarded only to the final recipient.

Three routing protocols perform variants of flooding. Epidemic replicates messages to all encountered peers, while PRoPHET tries to estimate which node has the highest “likelihood” of being able to deliver a message to the final destination based on node encounter history. Max Prop floods the messages but explicitly clears them once a copy gets delivered to the destination. In addition, Max Prop sends messages to other hosts in specific order that takes into account message hop counts and message delivery probabilities based on previous encounters

5. Simulation Results

While high-level movement models such as RWP, MBM, and SPMBM are simple to understand and efficient to use in simulations they do not generate inter-contact time and contact time distributions that match real-world traces, especially when the number of nodes in the simulation is small. In order to increase the reality of (human) node mobility, we have developed the Working Day Movement (WDM) model.

The message routing capability is implemented similarly to the movement capability: the simulator includes a framework for defining the algorithms and rules used in routing and comes with ready implementations of well known DTN routing protocols.

There are six included routing protocols: 1) Direct Delivery (DD), 2) First Contact (FC), 3) Spray-and-Wait, 4) PRoPHET, 5) Max-Prop, and 6) Epidemic. This selection covers the most important classes of DTN routing protocols: single-copy, n-copy and unlimited-copy protocols, as well as estimation based protocols.

Direct Delivery and First Contact are single-copy routing protocols where only one copy of each message exists in the network. In Direct Delivery, the node carries messages until it meets their final destination. In First Contact routing the nodes forward messages to the first node they encounter, which results in a “random walk” search for the destination node.

Simulation scenarios are built by defining the simulated nodes and their capabilities. This includes defining the basic parameters such as storage capacity; transmit range and bit-rates, as well as selecting and parameter the specific movement and routing models to use. Some simulation settings such as simulation duration and time granularity also need to be defined. The simulator is configured using simple text-based configuration files that contain the simulation, user interface, event generation, and reporting parameters. All modules have their high-level behaviour defined by their Java code implementation, but their details of their behaviour is adjustable using the configuration subsystem.

Many of the simulation parameters are configurable separately for each node group but groups can also share a set of parameters and only alter the parameters that are specific for the group. The configuration system also allows defining of an array of values for each parameter hence enabling easy sensitivity analysis: in batch runs, a different value is chosen for each run so that large amounts of permutations are explored.

For our simulations, we assume interpersonal communication between mobile users in a city using modern mobile phones or similar devices, using Bluetooth at 2 Mbit/s net data rate with 10m radio range. We observed that WLAN radios with 100m radio range have only a minor impact and do not change the elementary interaction characteristics so that we limit our discussion here to the Bluetooth case. The mobile devices have up to 100MB of free buffer space for storing and forwarding messages (flash memory may mostly be occupied by music or photos.)

Simulation have 544 and 1029 mobile nodes (humans, cars and trams) referred to as small and large scenario, respectively which move in a terrain of 8300X7300 m. The area is either an open space (for simple mobility models) or a part of the Helsinki city area as depicted in figure 4 (for map-based movement).

Table 1: Table showing the Performance Comparison

	Estimate Throughput								
CG	1	1.5	2	3	3.5	4	4.54	5.45	7.45
Paper	1	2	3	4	4.5	5.5	6.5	7	8.5
DTN	1	2	3	4	5	6	7	8	9

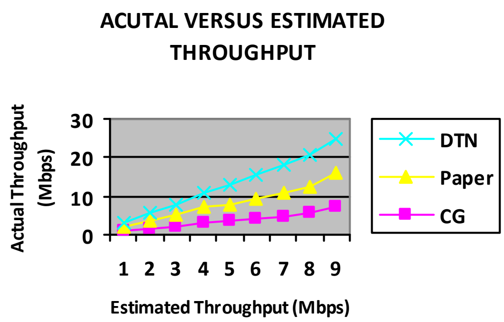

Figure 3: Vehicles/intersection v/s Entropy [bits]

6. Conclusion

An opportunistic networking evaluation system offers a variety of tools to create complex mobility scenarios that come closer to reality than many other synthetic mobility models. GPS map data provides the scenario setting and node groups with numerous different parameters are used to model a wide variety of independent node activities and capabilities. The Working Day Movement model allows recreating complex social structures and features such as scanning intervals add further aspects of reality and heterogeneity to the modelling. All these aspects may matter as our simple examples have shown. With its flexible input and output interfaces, the simulator can incorporate real-world traces and feeds from other mobility generators as well as generate mobility traces for use by other simulators. Its DTN framework currently includes six parameterizable DTN routing protocols and two types of application messaging. Its visualization component is used for instant sanity checks, deeper inspection, or simply to observe node movements in real-time which broadens its applicability beyond DTN. Particularly the integration with the DTN reference implementation allows creating test beds and emulations.

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