Performance Evaluation of Enhanced Location-Aware Content Delivery System in Wireless Wide Area Networks

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Abstract - A rapid growth of smartphones and tablet PCs is made in recent years that make computing devices nearly omnipresent at work, and on the road. Using the GPS, WiFi and cellular 3G interfaces built into these devices, mobile users are now adapted to having location-specific information easily. Location-aware information service like transportation schedules, restaurant items, shopping-mall maps, and movie trailers can be delivered through mobile applications. In contrast, providers can easily deploy a number of WiFi info-stations that deliver large content to vehicles passing by for future offline browsing. Although several researches have proposed systems for publishing content via roadside info-stations, they use simplified models to guide their design for scalability. Intuitively, per-vehicle throughput for unicast info-stations mortifies with the vehicles near the info-station, while broadcast info-stations are changeable. This paper provides a high-bandwidth info-station system that includes device-to-device data scavenging and so closer vehicles share data received from info-stations. It allows both unicast and broadcast throughput to balance with device density.

Keywords –Data scavenging, Info-station, Vehicle throughput.

1. Introduction

Using the WiFi, GPS, and cellular 3G interfaces built into these devices, mobile users are now comfortable to having location-aware records at their fingertips. Location- aware information services such as restaurant menus, shopping-mall information, transport schedules, departmental store circulars, and movie trailers can be delivered using mobile applications. Delivering content at high bandwidth, however, remains a noteworthy challenge for highly mobile users in vehicles, e.g., buses, cars and trains. Technologies such as satellite-based broadcasting are widely deployed, but offer low bandwidth links. Cellular-3G offers higher bandwidth, but only with considerable monthly costs. More importantly, cellular operators, overwhelmed by data usage on their networks, are implementing rate restrictions. Also WiFi offloading discourages mobile clients from using their mobile data services. Thus, it is believed that WiFi info-stations are the perfect substitute for setting up location-aware information services to users.

In our work, we reconsider the infestation-based data dissemination systems design using imminent from a large experimental measurement. We quantify the impact of vehicular concentration on both unicast- and broadcast-based systems.

Our measurements show that both unicast and broadcast have their limitations. Per-vehicle throughput degrades due to time sharing as vehicle density increases for unicast. The high loss rates of wireless channel severely mortify the distribution throughput for broadcast. Application level encoding at the infostation improves reliability, but the coding overhead limit the total attainable throughput.

We make four key findings.

1. Data propagation across vehicles reveals both spatial and temporal diversity.
2. Unicast with scavenging do better than relay with scavenging in other scenarios, except when both vehicle density and speed are high.
3. Data scavenging between vehicles can provide a scalable distribution service when combined with either unicast or broadcast.
4. For broadcasting infostations, scavenging develops distribution reliability without sacrifice throughput; for infostations using unicast, data scavenging permits distribution to scale with number of vehicles.

2. Disseminating Location-Specific Information with Starfish

The goal of this work is to design an efficient delivery system to issue location-aware content for mobile users on the move. In this section, we describe Starfish, an infostation-based content providing system for highly mobile users. We begin by defining the problem statement of issuing location-aware content, and then explain designs for Starfish based on roadside infostations using unicast or broadcast scenarios.

2.1 Location Specific Content Delivery

To issue location-aware content to mobile users with specified range in scalable ways is required. Consider for example, a family or friends driving on a highway road, where there are several services (e.g., hotel, theatre, fuel, health emergency) at the next 5-10 exits. Ideally, they would like to take an exit which has the best mixture of cost and services. Now assume, a road-side infostation is installed some miles ahead of the first exit.

As the vehicle passes by this infostation, they can download leaflets describing local amusement options and information such as shopping malls and fuel stations. Once they download all this information, they could read thoroughly it and make a decision on their best option. Similarly, in an urban scenario assume traveling around the city where several infestations are installed, each providing recent information about services offered in a place.

As users drive by the infostation, their smartphone obtain graphical menus of restaurants with colorful photos and nutritional data. They could also download digital maps of all stores, along with hours, sales, and available parking location. These types of content are typically organized as a collection of files, each provide details on an item or location of interest. While users would interactively browse the list and view specific files, this is not probable for highly mobile users, whose vehicle might be in range of an infostation for only 4-12 s (at highway speeds). Without time to interact with content, user devices must proactively fetch and cache the entire collection so users can browse them at their leisure offline.

2.2 Content Delivery with Unicast

Infostations with unicast can leverage MAC mechanisms like rate adaptation and packet retransmissions to achieve reliable data delivery. In our context, we need an infestation design that maximizes the profit of rate adaption to reliably broadcast the most number of files. Since the infostation can only send to one receiver at a time, it should broadcast to the in-range device with which it can establish the best connection.

If only a single device is in range, dissemination performance will be determined by the infostation's ability to retransmit lost packets and adapt transmission rate to diminish packet broadcast time. But when multiple vehicles are in infostation range, scheduling of the packets among multiple vehicles greatly affects the dissemination throughput. Scheduling involves both selecting the next packet to send and the vehicle to send that packet to.

As previously observed, unicasting packets using round-robin to all receivers brings down the throughput of the system to that of the farthest receiver. Clearly, better performance requires an enhanced scheduling algorithm. A good scheduling algorithm should consider changeable link quality at receivers.

If the goal is to maximize the average files delivered per-vehicle, the infostation should transmit to the in-range device with the best connection. To do so, each starfish infostation maintains an up-to-date scheduling list that contains an entry for every device in its radio range. To maintain this list, we use a simple hello protocol in which the infostation broadcasts hello packets every t ms. Each device that receives the hello packet unicasts a response to the infostation with the received signal strength embedded inside.

The infostation parses hello responses and ranks counter devices in the scheduling list by the embedded signal strength. Whenever it begins to transmit a new file, the infostation scrutinizes the devices with the best received signal strength, and makes a modification in it's transmit destination if and only if the new device has a considerably better signal strength than the currently scheduled device.

2.3 Content Delivery with Broadcast

Using broadcasts for infostation dissemination has the benefit that per-vehicle throughput is not a function of the number of devices in range. This makes the infestation inherently more scalable. However, for broadcasts, the 802.11 MAC family does not use acknowledgments, packet retransmissions, or rate adaptation mechanisms. As it later confirm using measurements, this produces significant packet losses in our highly mobile environment. In addition, no rate adaptation means that infostation transmissions will be limited to a basic parameterized rate. The Starfish broadcast infostation design is simple.

The infostation iterates over all files, broadcasting all files in order. Any device in range can receive the packet, which could be corrupted due to random propagation effects. Thus, the challenge is to increase resilience to packet losses. Starfish can leverage several existing techniques to improve resilience in broadcast data delivery, ranging from physical layer techniques like smart antennas to application layer solutions such as forward error correction and source coding. Many of these, however, come at the cost of high complexity and overhead.

This simple method segments each file into blocks of m packets, and encodes each block independently into n packets. From our measurements, we monitor that packet loss is often bursty. Thus rather than broadcasting all packets in each block contiguously, the infostation interleaves encoded packets of multiple blocks.

3. Algorithms

3.1 Implementation of a General Sender-Based Algorithm

Algorithm 1 shows the basic structure of our proposed sender-based broadcasting algorithm. As shown in Algorithm 1, each node schedules a broadcast for a received message if the node is selected by the sender and if it has not scheduled the same message before. Clearly, each message is broadcast once at most by a node, which is similar to Liu et al.'s algorithm.

In the algorithm each node may only schedule a broadcast when it receives a message for the first time. In contrast, in Algorithm 1, a broadcast schedule can be set at any time. For example, a message can be dropped after the first reception but scheduled for broadcast the second time. Clearly, the main design issue in Algorithm 1 is how to select the forwarding nodes.

This module proves that in a collision-free network, Algorithm 1 can achieve full delivery if it uses a slice-based selection algorithm to select the forwarding nodes.

A General Sender-Based Algorithm

1. Process information from message m received
2. If m has been scheduled for broadcast or does not contain node's id then

```
Discard the message
Else
    Set a timer
End if
When timer expires
    Select subset of neighbors to promote i.e., forward the message
    Append the list of forwarding node to the message
    Schedule a broadcast
```

The sender-based broadcasting algorithms can be divided into two subclasses. In the first subclass, each node decides whether or not to broadcast solely base on the first received message and drops the rest of the same messages that it receives later. In the second subclass of sender-based broadcasting algorithms, each node can decide whether or not to broadcast after each message reception. However, if a node broadcasts a message, it will drop the rest of the same messages that it receives in the future.

3.2 Implementation of a General Receiver-Based Algorithm

Algorithm 2 shows a general approach used in several receiver-based broadcasting algorithms. The proposed receiver-based broadcasting algorithm employs this approach. Clearly, the main design challenge of this algorithm is to determine whether or not to broadcast a received message. A trivial algorithm is to refrain broadcasting if and only if all the neighbors have received the message during the period.

Although this algorithm is simple to implement, it has limited effect in reducing the number of redundant broadcasts. Suppose NA's defer time expires at t0. Using the above strategy, node NA will broadcast if some of its neighbors (at least one) have not received the message by t0. However, this broadcast is redundant if all such neighbors receive the message from other nodes after time t0. This scenario typically occurs when t0 is small compared to the maximum defer time.

The proposed a novel receiver-based broadcasting algorithm that can significantly reduces redundant broadcasts in the network. The receiver-based broadcasting algorithm, the receiver of the message decides whether or not to broadcast the message. Therefore, a potential advantage of receiver-based broadcasting algorithms over sender-based ones is that they do not increase the size of the message by adding a list of forwarding nodes.

A General Receiver-Based Algorithm

```
Process information from the message M received
If M has been received already then
    Drop the message
Else
    Set a defer timer
End If
When defer timer expires
    Decide whether or not to schedule a broadcast
```

The main design challenge of Algorithm 2 is to determine whether or not to broadcast a received message. A trivial algorithm is to refrain broadcasting if and only if all the neighbors have received the message during the defer period. Although this algorithm is simple to implement, it has limited effect in reducing the number of redundant broadcasts. Suppose NA's defer time expires at t0.

Using the above strategy, node NA will broadcast if some of its neighbors (at least one) have not received the message by t0. However, this broadcast is redundant if all such neighbors receive the message from other nodes after time t0. This scenario typically occurs when t0 is small compared to the maximum defer time. In the next section, a responsibility-based scheme (RBS) is introduced that further reduces the redundant broadcasts without any changes in the MAC-layer defer-time design.

3.3 Responsibility Based Scheme

Input: $List_A$: List of all neighbors of N_A, and $List_B$: List of broadcasting neighbors
Output: true or false

```
$List_C \leftarrow List_A$
for i = 1; $i \le$ length(ListC); i++ do
    for j = 1; $j \le$ length(ListB); j++ do
        if dist($List_C[i]$,$List_B[j]$) $\le R$ then
            removeElement($List_C[i]$;$List_C$)
            break
        end if
    end for
end for
ListD $\leftarrow$ ListA — ListC
for i = 1; $i \le$ length($List_C$); i++ do
```

```
    check ← true
    for j = 1; j ≤ length($List_D$); j++ do
        if dist($List_C$[i],$List_D$[j]) < dist($List_C$[i],$N_A$) then
            check ← false
            break
        end if
    end for
    if check then
        return (false)
    end if
end for
return (true)
```

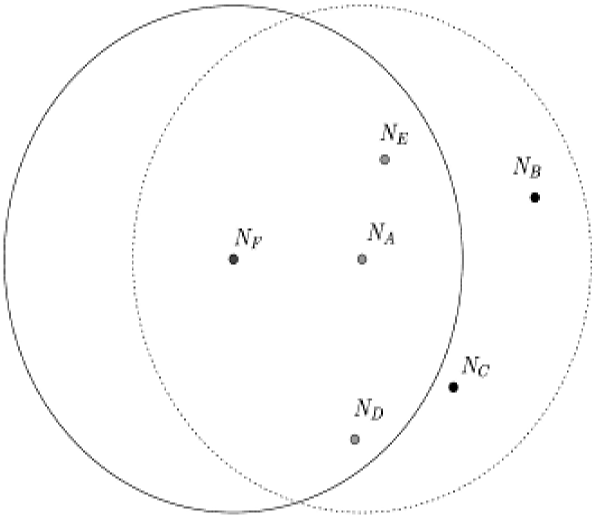

Fig 3.3.1 An Example of an Rbs Decision

As shown in Fig. 3.1 N_A has five neighbors. Suppose that N_A has received a message from N_F. Note that N_A has the position of all its neighbors. Therefore, it can find that N_E and N_D have received the message but N_B and N_C have not. As shown in Fig. 3.1, N_A is not required to broadcast because

$$\overline{BE} < \overline{BA} \quad \text{and} \quad \overline{CD} < \overline{CA}.$$

4. Result and analysis

The main objective of efficient broadcasting algorithms is to reduce the number of broadcasts. Therefore, to consider the ratio of broadcasting nodes over the total number of nodes as the metrics is used to evaluate the performance of the proposed broadcasting algorithms. The metric is evaluated against two parameters: transmission range and node density. The implemented is carried out using C#.Net language as windows application. The broadcasting algorithms in a mobile wireless setting are processed. The nodes were initially distributed using uniform distribution. Device-to-device data scavenging is incorporated in the Starfish prototype and its performance is evaluated using the windows application and the result is found to be satisfied. Algorithms are processed at each data rate for the broadcast infostation scenario, and three test runs for different fleet sizes for the unicast infostation scenario are carried out.

4.1 Scavenging effectiveness:

To understand how well the data scavenging protocol performs in practice, it is compared against an optimal scavenging scheme. The optimal scavenging scheme assumes each device can obtain any packet received by other devices in the fleet, thus providing an upper bound on the scavenging performance. The broadcast and unicast, the number of files received by Starfish devices compared to optimal scavenging. For reference, it also includes the result of files that a vehicle receives directly from the infostation assuming no scavenging. The Starfish's data scavenging is highly effective and reaches the optimal recovery in almost all cases. For both unicast and broadcast scenarios, vehicles in the Starfish system receive significantly more files after scavenging than they directly receive from the infostation

4.2 Findings

1. Many suspect that scalability with increasing vehicle density is the major challenge for info-stations.
2. Per-vehicle throughput for unicast info-stations degrades with the number of vehicles near the info-station.

3. Partial file information transmission is possible to vehicle nodes and so the nodes are not possible to obtain the information.
4. The thesis provides a high-bandwidth and scalable info-station system that incorporates device-to-device data scavenging, where nearby vehicles share data received from the info-station. It allows both broadcast and unicast throughput to scale with device density.
5. In existing systems, the nodes need to select more nodes in the transmission range to broadcast the information and so flooding occurs.
6. In proposed system, in worst case scenario, i.e., if the number of neighbor nodes is more in the transmission range, the selecting maximum 11 nodes for single hop is enough to broadcast the information to the destination node.
7. A node N_A is not responsible for a neighbor N_B if N_B has received the message or if there is another neighbor N_C such that N_C has received the message and N_B is closer to N_C than it is to N_A. The Algorithm first uses this information to determine which neighbors have not received the message. It then returns false if and only if it finds a neighbor N_B that has not received the message and length of AB □□length of BC, for any N_A's neighbor N_C that has received the message

Chart Data
Before Scavenging

	8 KM	48 KM	96 KM
1	90	110	1000
2	85	104	990
3	80	101	950
4	50	90	700
5	30	80	600
10	20	30	300
20	8	20	110

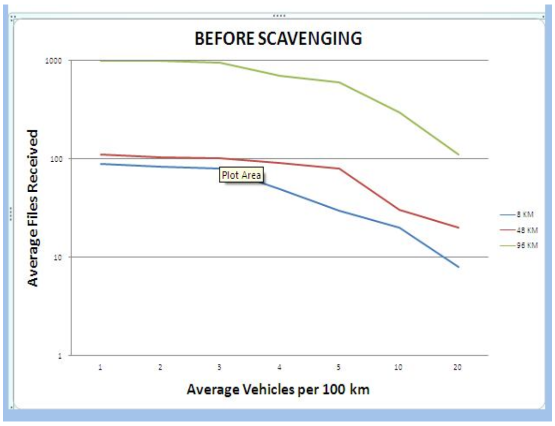

Fig 4.1 Before Scanvenging

Before Scavenging: The baseline performance of unicast infostations is examined with a hello message interval of 200 ms. Fig. 4.1 shows that as density increases, average per-vehicle throughput decreases as infostation bandwidth is shared by more vehicles.

Assuming signal strength decreases monotonically with distance, it is roughly estimate the amount of time a vehicle gets scheduled (by having the best signal strength in the fleet) as spacing/speed. This is confirmed by the experiments, and explains the trend in Fig. 4.1 a where per-vehicle throughput scales inversely with vehicle spacing and speed. We will show later how the hello interval also impacts unicast performance.

After Scavenging

	8 KM	48 KM	96 KM
1	400	800	5000
2	550	900	6000
3	600	1100	6500
4	700	2000	9000
5	800	2500	9500
10	800	2500	9500
20	800	2500	9500

After Scavenging: Fig. 4.2 shows that dissemination throughput after scavenging increases significantly with vehicle density, similar to those observed in our test bed experiments. This is because as vehicle density increases, the infostation benefits from more multiuser diversity and therefore a greater portion of its unicast transmissions are at higher rates.

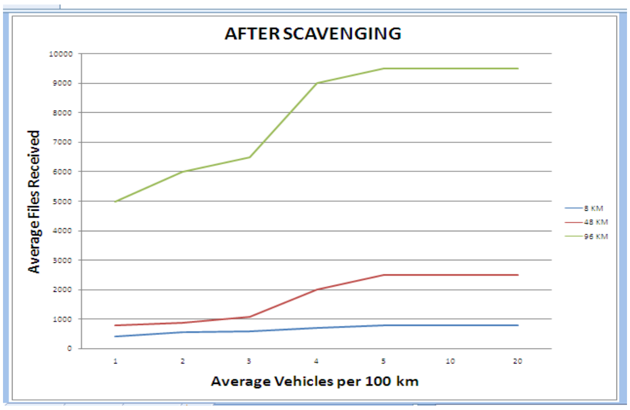

Fig 4.2 After Scavenging

5. Conclusion

This thesis presents the measurement-based design of an info-station-based content delivery system, where vehicles passing by a roadside info-station proactively fetch and cache content for offline browsing. It finds that both unicast- and broadcast-based systems fail to scale as vehicle density increases. In addition, it is observed that data dissemination exhibits both temporal and spatial diversity across vehicles.

It also proposes to exploit this diversity via data scavenging, where vehicles passing by the info-station share data between them to both recover from wireless loss and extend the effective range of the data transmission. Through detailed experiments, it shows that the scavenging techniques achieves close to the optimal predicted performance.

In addition, an efficient broadcasting algorithm for ad-hoc network using improved mechanism in worst case scenario is developed. In particular, RBS based receiver algorithm to address the broadcasting problem is proposed. It proves the correctness of the algorithm and demonstrated the effectiveness. The proposed algorithms provide powerful broadcasting especially when the number of nodes in more in transmission ranges of sender node.

The new system eliminates the difficulties in the existing system. It is developed in a user-friendly manner. The system is very fast and any transaction can be viewed or retaken at any level. It reduces the time to analyze the broadcasting algorithm.

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