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A Comprehensive Study on Vehicular Ad-Hoc Delay Tolerant Networking for Infrastructure-Less Areas

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Abstract: *Generally, traditional networks presume the presence of some path between endpoints. Today, however, new applications, environments and types of devices are challenging these assumptions. In Delay Tolerant Networks (DTNs), an end-to-end path from source to destination may not exist. Nodes may connect and exchange their information in an opportunistic way. This book represents a broad overview of DTNs, particularly focusing on Vehicular Ad-hoc DTNs, their main characteristics, challenges and our research on this field. In the near future, cars are expected to be equipped with devices that will allow them to communicate wirelessly i.e. Wi-Fi. However, there will be strict restrictions to the duration of their connections with other vehicles, whereas the conditions of their links will greatly vary; DTNs as well as Ad-hoc DTNs present an attractive solution. Therefore, Vehicular Ad-hoc DTNs constitute an attractive research field. For practical implementation, we have used two Android devices for a little range of Wi-Fi. So, by this we are trying to give us better accuracy to go further. Thorough out this document, we have mentioned those techniques we came across and also those techniques and algorithms that we used in our proposed method.*

Keywords: *Ad-hoc network, contact schedule, data delivery scheme, delay-tolerant networking, Wi-Fi.*

I. Introduction

The existing Internet protocols do not work well for some environments, due to some fundamental assumptions built into the Internet architecture that an end-to-end path between source and destination exists for the duration of a communication session, end-to-end loss is relatively small, all routers and end stations support the TCP/IP protocols that applications need not worry about communication performance. But Delay Tolerant Network (DTN) architecture is conceived to relax most of these assumptions byusing storage within the network to support store-and-forward operation over multiple paths and over potentially long timescales[1]. Our motivation isto a create network to transfer data in infrastructure-less areas.Such scenario can be in highways where there is no fixed structure or tower to transfer data. Create network in such scenario, we can use Ad hoc Delay Tolerant Network where- we can use each vehicle, which can be regarded as mobile node. Each mobile node, i.e., vehicle is equipped with wireless networking devices, i.e., Wi-Fi device, smart phone. Information data must transfer in hop by hop manner from source to destination. We have tried to do it practically in a little scale. So, that we can implement it in urban areas and if possible for rural areas in our country (Bangladesh). For that we are trying to develop our practical implementation segment. This is a great chance to connect people from the remote corner of the country.

II. Theoretical Overview

2.1 Delay-tolerant networking (DTN)

Delay-tolerant networking (DTN) is an approach to computer network architecture that seeks to address the technical issues in heterogeneous networks that may lack continuous network connectivity. A DTN is a network of smaller networks. It is an overlay on top of special-purpose networks, including the Internet [2]. Examples of such networks are those operating in mobile or extreme terrestrial environments, or planned networks in space.Recently, the term disruption-tolerant networking has gained currency in the United States due to support from DARPA, which has funded many DTN projects [3]. Disruption may occur because of the limits of wireless radio range, sparsely of mobile nodes, energy resources, attack, and noise.

Many evolving and potential communication environments do not conform to the Internet's underlying assumptions. These environments are characterized by intermittent connectivity, asymmetric data rates,high error rates, intermittent connectivity etc.

DTNs overcome the problems associated with intermittent connectivity, long or variable delay, asymmetric data rates, and high error rates by using store-andforward message switching. This is a very old method, used by

pony-express and postal systems since ancient times. Whole messages (entire blocks of application-program user data)—or pieces (fragments) of such messages—are moved (forwarded) from a storage place on one node (switch intersection) to a storage place on another node, along a path that eventuallyreaches the destination.
Utilizing the DTN approachrequires significant effort developing additional functionality and integrating them. Delay-Disruption Tolerant networks make use of "Store – and – Forward", mentioned in Fig.1 below, technique within the network in order to compensate Intermittent Link Connectivity. Store-and-forwarding methods are also used in today's voicemail and email systems, but these systems are not node-to-node relays (as shown above) but rather star relays; both the source and destination independently contact a central storage device at the center of the links [2].

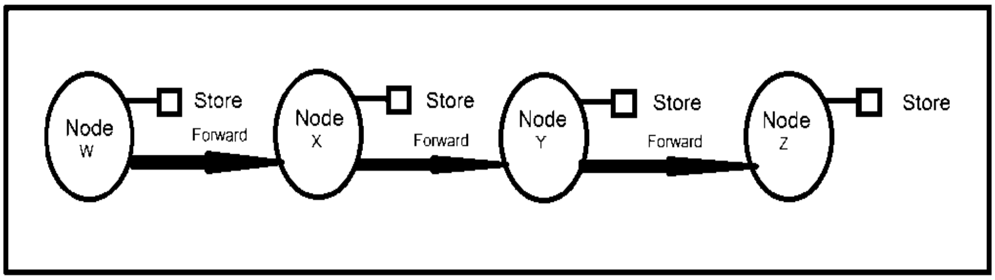


Fig.1: Store and Forward Technique [4]

When the link is up, the source node has an opportunity to send the data to another end. In DTN, this opportunity is called "Contact". More than one contact may be available between a given pair of nodes. For example: a node might have both high-Performance, expensive connections and a Low-Performance cheap connection simultaneously for communication with the same direction. The "Contact Schedule" is the set of times when the Contact will be available, (i.e.) upon considering the Contact's in GraphTheory, it is a Time-Varying Multi-Graph. The DTN architecture proposes to use this network by forwarding the complete Data/Message over eachhop. These Messages/Data will be buffered at each intermediate node, potentially on Non-Volatile Storage. This enable messages to wait until the Next-Hop is available; which may be a long period of time [5].

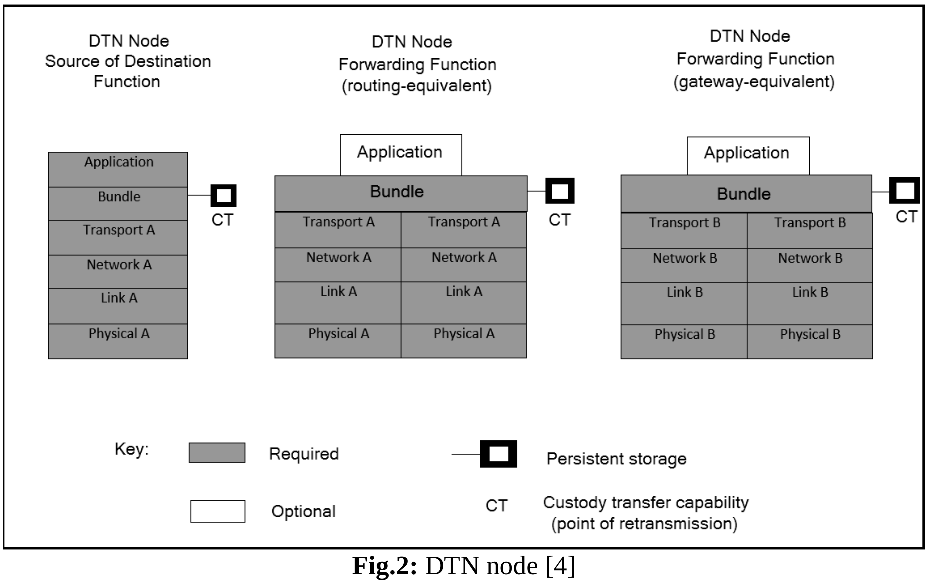


Fig.2: DTN node [4]

In above Fig.2, we can see the structure. Unlike the TCP/IP, the DTN does not assume a continuous end-to-end connection. In its design, if a destination path is un-reachable, the data packets are not discarded but instead each network node keeps custody of the data as long as necessary until it can positively communicate with other nodewhich ensures that the information does not get lost when no intermediate path to the destination exists [2]. The DTN acts as an overlay above Transport Layers of the networks it interconnects and provides key services such as in-networkdata storage and retransmission, interoperable naming, authenticated forwarding and a coarse-grained class of service. TCP/IP suite functions poorly when faced with very long delay paths and frequent network partition. These problems are aggravated by the end nodes that have Severe Power constraints or Memory constraints.

2.2 Ad-hoc Network

Ad-hoc is a Latin word that means "for this purpose".A wirelessad-hoc network is a decentralized type of wireless network.The network is ad hoc because it does not rely on a pre-existing infrastructure, such as routers in wired networks oraccess points in managed (infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamically on the basis of network connectivity. In addition to the classic routing, ad hoc networks can use flooding for forwarding the data.

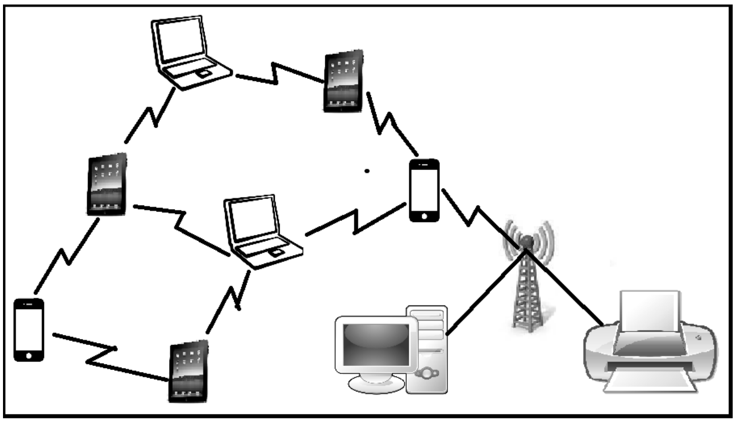


Fig.3: Ad-Hoc Network [4]

An ad hoc network typically refers to any set of networks where all devices have equal status on a network, in above Fig.3, we can see that and are free to associate with any other ad hoc network device in link range. Ad hoc network often refers to a mode of operation of wireless networks.
The decentralized nature of wireless ad hoc networks makes them suitable for a variety of applications where central nodes can't be relied on and may improve the scalability of networks compared to wireless managed networks, though theoretical and practical limits to the overall capacity of such networks have been identified.
Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural disasters or military conflicts. The presence of dynamic and adaptive routing protocols enables ad hoc networks to be formed quickly. Mobility, multi-hopping, self-organization and energy conservation are some important aspects of ad-hoc network.

III. Study On Vehicular Ad-Hoc DTN For Infrastructure-Less Areas

3.1 Model Scenario

We considered a highwaywhere vehicles are moving.We wanted to send some data from one end to the other end.But if there is no end to end connection between the two ends,it is not possible to do this.That’s why we build a Vehicular Ad-Hoc Delay Tolerant Network.In this case,each vehicle(truck or car) works as an individual node and router having a Wi-Fi device with Wi-Fi range and storage system.Whenever the Wi-Fi range of two cars/trucks overlap,they connect each other creating an Ad-Hoc Network .The sinksat two ends can simultaneously generate and receive data.The generated data by sink 1 or sink 2is delivered to sink 2 or sink 1respectively by the cars.
The basic algorithm to delivery data was –“**store and carry**”.Every vehicle collected data from the sink and stored it.Then it carriedthe data by itself and whenever it found any other vehicle within its Wi-Fi range,it forwarded the collected data.Thus data delivery was done from one end to the other end. We needed some parameters, those are-
Sink: There were two sinks at two ends,sink 1 and sink 2.Each sink could generate and receive data simultaneously and the generated data was delivered by the vehicles.
Road: We considered the road consisting of two lanes. For our modelwe also considereda portion of the highway with a length of 5 km.We took the lanes ideal where there was no bending and there was no section or sub-section.
Vehicle: We took car and truckas vehicles.Car and truck could move in opposite direction.We assumed that,every vehicle had a data storage system and a power supply that supplies power.Vehicles would always try to connect to each other within their Wi-Fi range.If a vehicle found any other vehicle within its range,it would deliver the data.The new vehicle then carried the data until it found another vehicle within its range.Thus data was stored,carried and forwarded to the sink. We also assumed that the vehicles would not change their route.
Wi-Fi range: Wi-Fi range of each vehicle was 250 m. Within this range a vehicle could connect with other vehicles and transfer data.

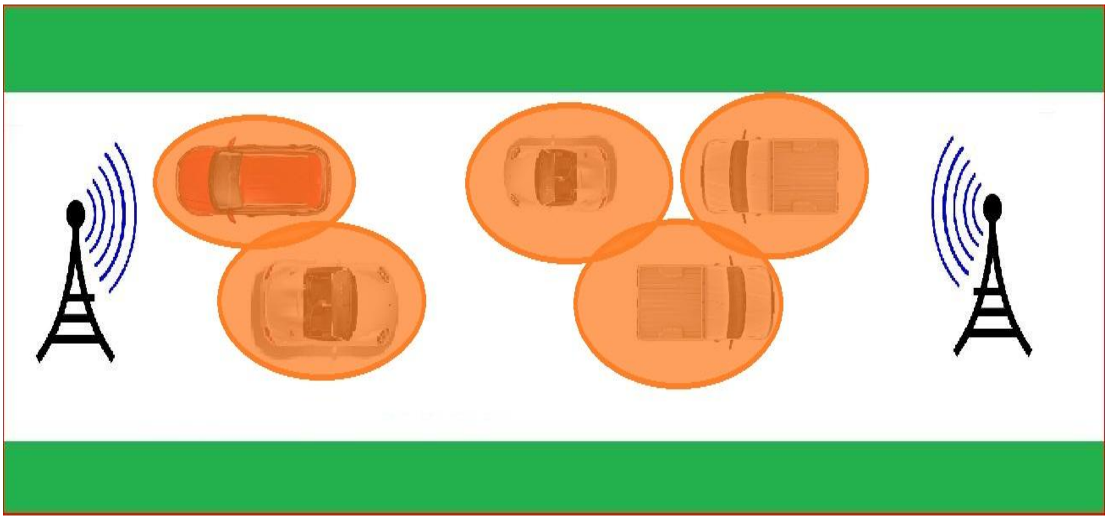
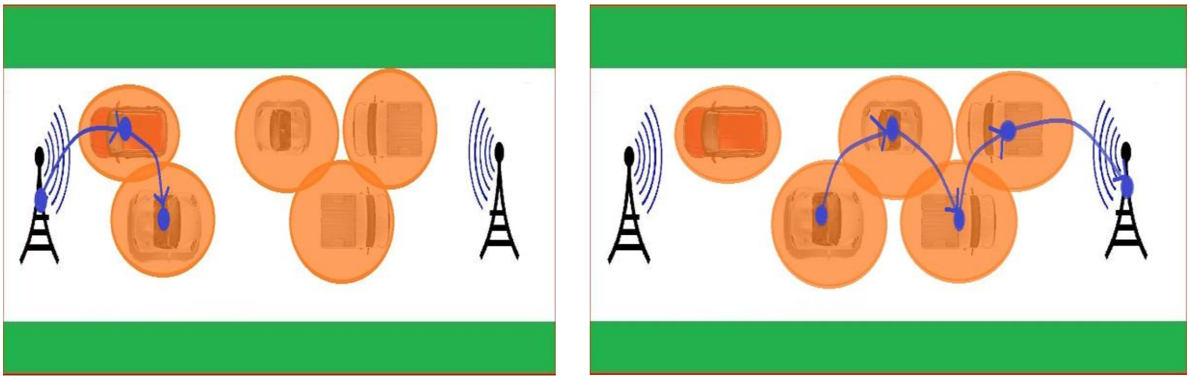


Fig.4: Wi-Fi ranges overlapping

In the above Fig.4, we can see that the vehicles are overlapping their Wi-Fi ranges while moving or passing each other in highway road. Orange circles represent the Wi-Fi ranges here.



(a) (b)

Fig.5: Data passing (a) Data is passing from sink to a vehicle, (b) Data is reaching its destination to other sink

So here in above Fig.5, we can see that data is passing from left sink and then one vehicle to another vehicle after connecting their Wi-Fi. Finally it sends data to the right sink. So by this, data can be transferred.

Speed: We ran our simulation basically for the speeds of 36 km/h.We considered the speed to be constant for the whole time.

3.2 Data Delivery Schemes

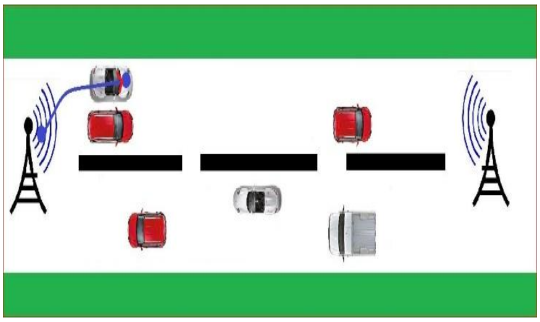
There are 3 ways to deliver data. These are: (i) One way one direction, (ii) Multi-hop one direction, (iii) Multi-hop multi direction

3.2.1 One Way One Direction

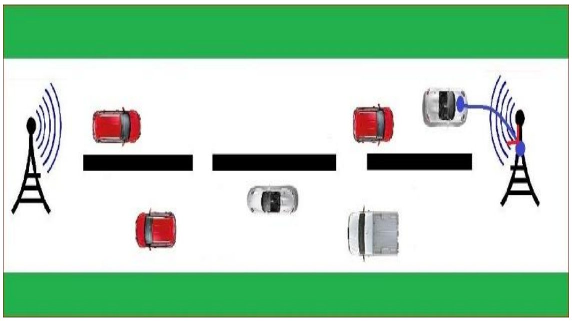
One way one direction is the first of our three schemes for delivering data from one place to another. Here direction refers to data direction not conventional direction like north, south etc. In one way one direction, the direction of data does not change. We already know the basic strategy is to 'store, carry and forward'. But in one way one direction there is no forwarding of data except for delivering it to the sink. Here there is no vehicle to vehicle data transfer.

A vehicle (car, truck, motorcycle, cycle etc.) collects data from the sink, stores the data in its storage system and moves towards its destination. On its journey it does not forward data to any other vehicle even if the other vehicle is within the Wi-Fi range. This is the basic difference between this scheme and the other two schemes. In other schemes data is forwarded from one vehicle to the other vehicle in hop by hop manner. But we are going to discuss it later elaborately.

In one way one direction there is no hopping of data from one vehicle to the next vehicle. Here hopping occurs in only twice-a) While receiving data from the sink andb) Whiledelivering data to the sink.



(a) Data starts to pass from sink to vehicle



(b) Data reaches its destination in only forward direction

Fig.6: One way one direction

In the Fig.6, we see an example of one way one direction. Here we see that, there are two sinks A and B and they are far apart from each other. Every vehicle collects its data from the sinks and is carrying its own data and proceeding towards their respective destination.
Advantages: Less chance of data loss and data security is ensured.
Disadvantages: Data rate is slow.

3.2.2 Multi-Hop One Direction
In multi-hop one direction a vehicle collects data from one sink and if it finds another vehicle moving in the same direction and within its Wi-Fi range then it forwards the data to the next vehicle and the data is then stored on the second vehicle. After one hopping, if there are no vehicles within the Wi-Fi range, then that vehicle stores the data until it finds another vehicle. Whenever the second vehicle is in contact with another vehicle it forwards the data to that vehicle. This hopping or forwarding continues until the data reaches the destination (the sink).In multi-hop one direction every vehicle receives data from the sink and they move forward and keep checking for a vehicle ahead of them and they measure the Wi-Fi range. If their Wi-Fi range overlaps then they connect with each other. The vehicle which is lagging behind forwards the data to the next vehicle.

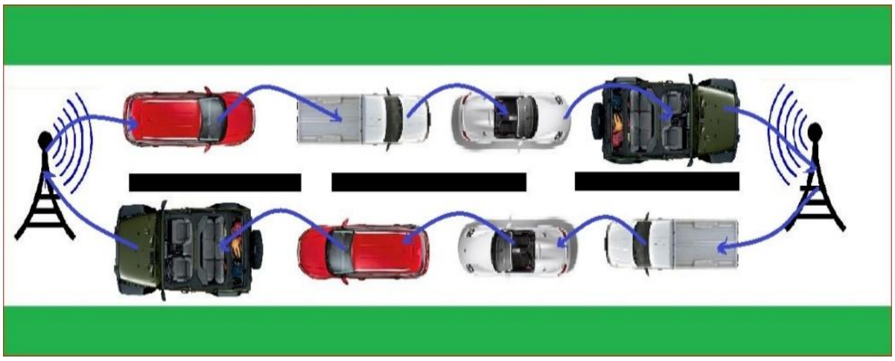


Fig.7: Multi-hop one direction

Here (Fig.7) is an example of multi-hop one direction data transfer. Like in the previous case there are two sinks A and B. There are some vehicles on the road-some are moving from sink A to sink B and some are moving from sink B to sink A. every vehicle is carrying its own data as we see in the figure. Whenever two vehicles are within the Wi-Fi range of each other we see hopping of data as described earlier.
Advantage: Data delivery rate is faster.
Disadvantage: Data confidentiality can be exposed.

3.2.3 Multi-Hop Multi-Direction
In multi-hop one direction there is no hopping of data to the vehicles of the opposite direction but in multi-hop multi-direction data hops into the vehicle of the same direction as well as vehicles of the opposite direction.
While moving towards destination, every vehicle tries to hop its data to a vehicle that is ahead it and on the same direction. If there is no vehicle on the same direction, then it tries to hop its data to a vehicle coming towards it. The vehicle from the opposite direction tries to hop the data in a vehicle of the same direction or in the opposite direction. For the case of same direction, the vehicle hops the data to a vehicle that is behind it. Because there is no point in delivering the data into a vehicle that is ahead of it. In that case the data is going to be carried into the same direction it has come from.

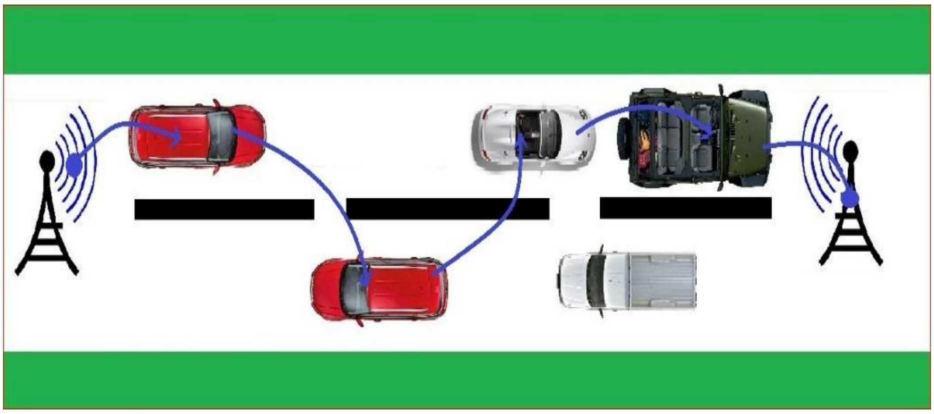


Fig.8: Multi-hop multi-direction

From the above Fig.8, we find that there are four vehicles–car1, car2, car3 and car4. Car1 and car4 are moving from sink 2 to sink 1 whereas car2 and car 3 are moving from sink 1 to sink 2.
Suppose sink 2 wants to send some data to sink 1. So it passes the data to car 4. If it is one way one direction, then car 4 is going to carry the data all the way to sink A. If it is multi-hop one direction, then car 4 tries to hop the data to the next vehicle in the same direction. But there is no vehicle available next to car 4. So it carries the data until it can pass the data to another vehicle.
Advantage: Data rate is faster than previous two delivery schemes.
Disadvantages: (a) Data loss is more (b) Data confidentiality is difficult to maintain.

3.3 Simulation: For simulation, we used "**NetLogo 5.0.3**" software. It is an open source and user friendly software.
3.3.1 Simulation Setup: We built our simulator according to our model scenario. We selected the road length to be 5 kilometers. The road is a two lane road. We chose car and truck as our default vehicles. The Wi-Fi devices have Wi-Fi range of 250 meters. Every sink generates 300 data and delivers it to the other sink. That means sink A generates 300 data which is delivered to sink B via all the three schemes one way one direction, multi-hop one direction, multi-hop multi-direction separately. We considered 30 vehicles in 5kilometerof road length. We fixed our model setup that means for all three schemes the position of all vehicles were fixed in order to maintain similarity. The speed of all the vehicles was constant during the whole simulation and we chose different speeds of 36 km per hour.

No	Parameters	Value
01.	Length of the road	5 kilometers
02.	Number of data (for a single sink)	20 and 30
03.	Speed of the vehicle	36 km/h
04.	Number of vehicle	40
05.	Wi-Fi range	250 meter

Table1: Simulation Setup

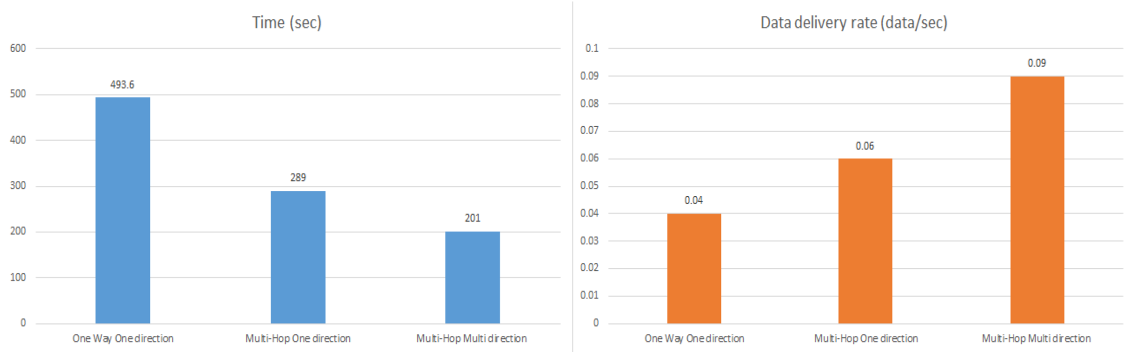
We ran our simulation on a platform (Personal Computer) with the following configuration:

1.	Machine name	EXTREME
2.	Operating System	Windows 7 Professional 64-bit (6.1, Build 7600)
3.	Language	English (Regional Setting: English)
4.	System Manufacturer	BIOSTAR Group
5.	System Model	G41-M7
6.	BIOS& DirectX Version	Default System BIOS& DX 11
7.	Processor	Intel(R) Core(TM)2 Quad CPUQ8400 @ 2.66GHz (4 CPUs), ~2.7GHz
8.	Memory	4096MB RAM (OS-4062 MB RAM)
10.	Page File	1159MB used, 6961MB available
11.	Windows Dir	C:\Windows
12.	System DPI Setting	96 DPI (100 percent)
13.	DxDiag Version	6.01.7600.16385 32bit Unicode

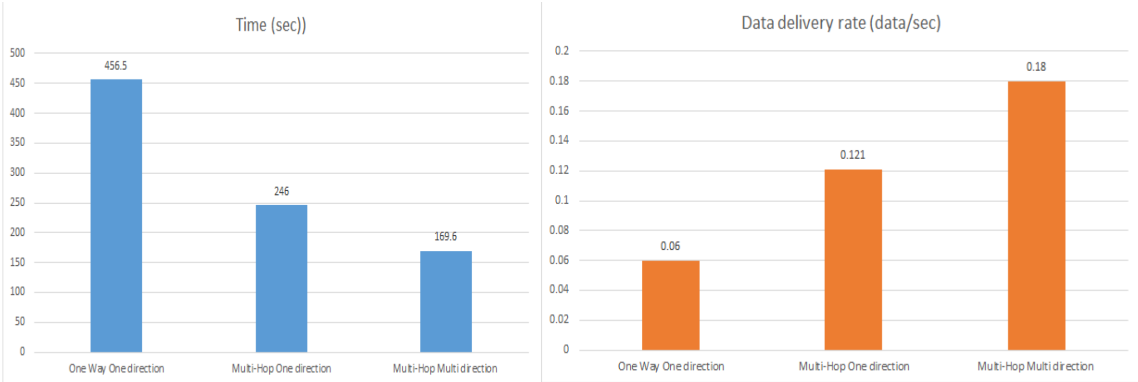
Table 2: System Configuration

IV. Results And Discussion

We ran our simulation for road length of 5 km and vehicle speed was chosen to be 7 km/h, 15 km/h, 30 km/h and 36 km/h. For each case, the twenty data was sent by sink 1 and received by sink 2 at first step. Later, thirty data was sent by sink 2 and received by sink 1.

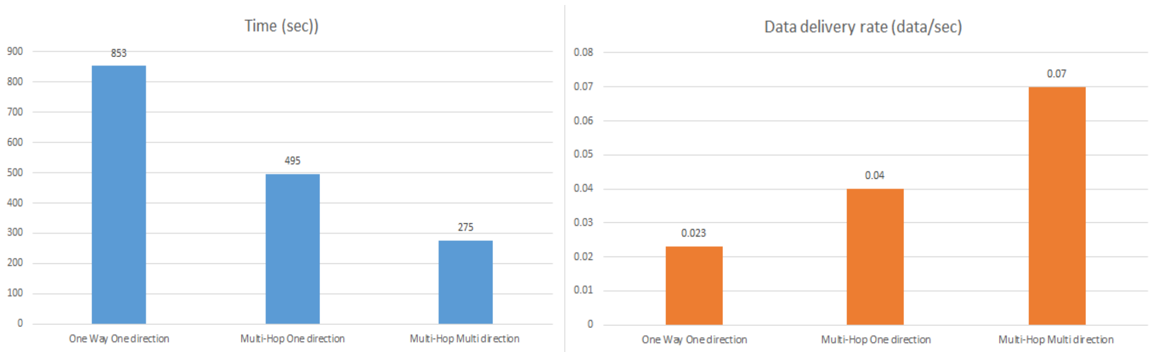


(a) Data sent by sink 1, received by sink 2

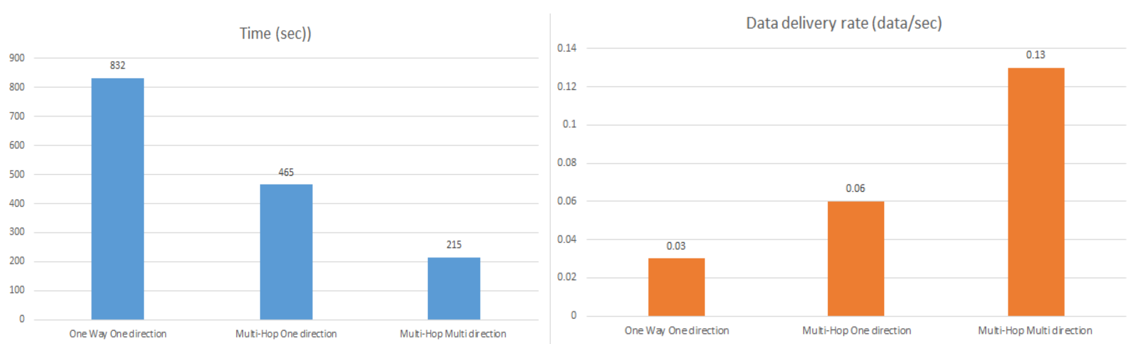


(b) Data sent by sink 2, received by sink 1

Fig.9: Graphical representation for 7 km/h vehicle speed ('x-axis' represents data delivery schemes)



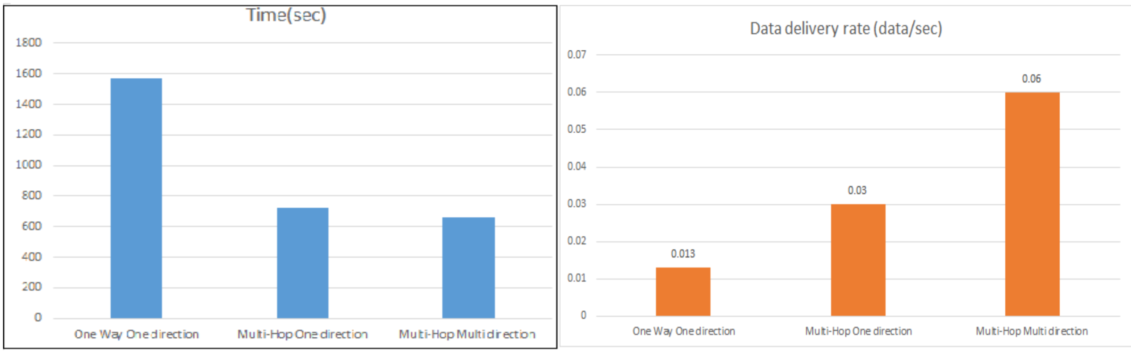
(a) Data sent by sink 1, received by sink 2



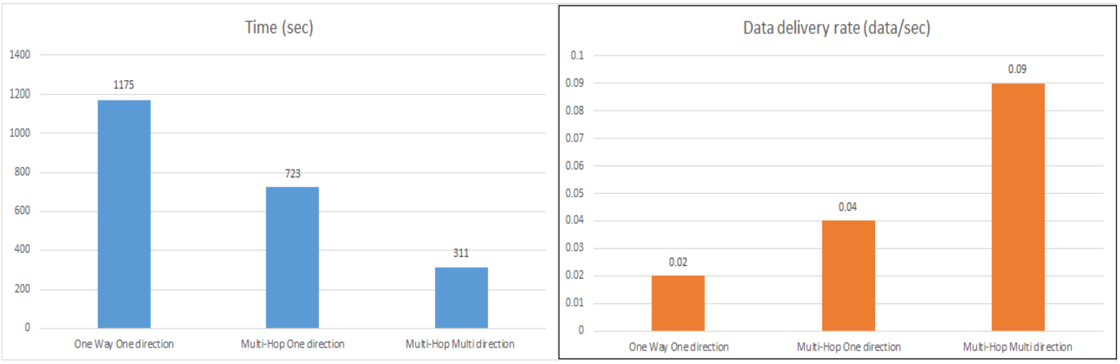
(b) Data sent by sink 2, received by sink 1

Fig.10: Graphical representation for 15 km/h vehicle speed ('x-axis' represents data delivery schemes)

We found that the data delivery rate was highestin multi-hop multi-direction and lowestin one way one direction. We also saw that data delivery rate increased as speed of vehicles increased.

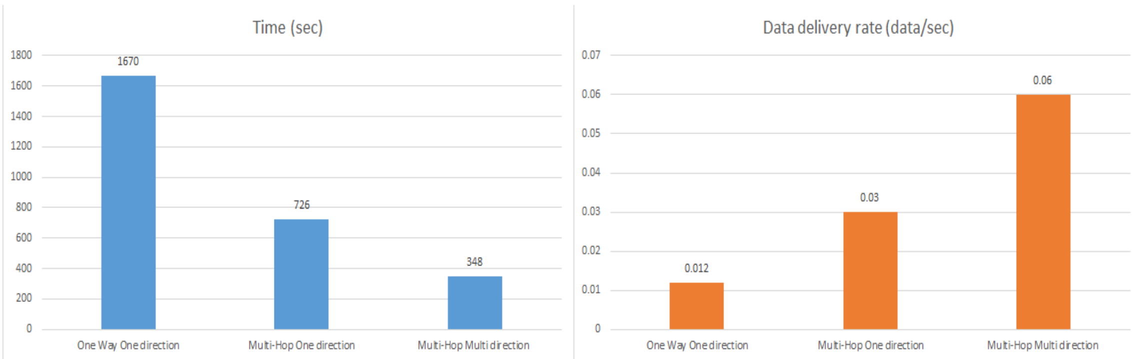


(a) Data sent by sink 1, received by sink 2

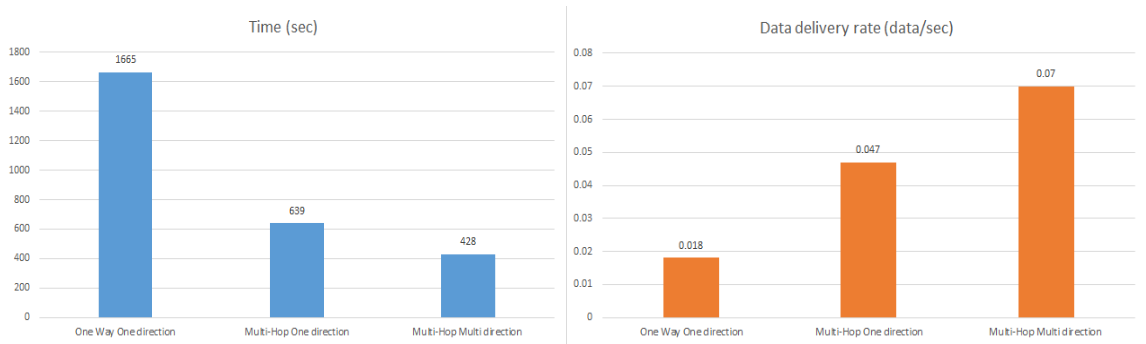


(b) Data sent by sink 2, received by sink 1

Fig.11: Graphical representation for 30 km/h vehicle speed ('x-axis' represents data delivery schemes)



(a) Data sent by sink 1, received by sink 2



(b) Data sent by sink 2, received by sink 1

Fig.12: Graphical representation for 36 km/h vehicle speed ('x-axis' represents data delivery schemes)

Above these tables and graphical representations for 7 km/h, 15 km/h, 30 km/h and 36 km/h, we can visualize that for multi-hop multi direction scheme, data delivery rate is highest and taken time is lowest. It matched with the theory. We simulated 10 times for every speeds. So far we had understood that multi-hop multi direction scheme was the best option to transfer data.

For practical implementation we took two Android devices. Then we developed an application suitable for Android 4.1 or 4.1+ versions. By this we did connect those devices by their Wi-Fi and they passed their data from one to another.

V. Conclusion

Though our research work has showed some performances but not good, there can be done a lot of improvements. There are some complexities that can be handled for future research on this topic. We are trying to develop the application and make it more suitable for practical implementation. But to do this perfectly, we have to face some challenges. We tried to give some extensions. Those are-
Wi-Fi connections and its ranges. Without good Wi-Fi coverage, we can't implement our research. Speed of the vehicles is a very big issue for this. Because speed varies time to time. So without perfect match, we can't transfer our data. In above work, we are only able to transfer data file. So transferring different types of data can be a complex work to do. Security assurance is a very big challenge for this and it must be maintained. For such limitations we don't expect perfect accuracy for our thesis.
Now we can send data between two devices when they overlaps their Wi-Fi ranges. So it can be a great challenge to pass the data in high speed and in extreme condition i.e. natural calamities.Ad-hoc DTNs is a technology that is very new to the developing countries i.e. Bangladesh. If we can overcome these problems completely, there can be many extensions for our topic in future research and we can implement something bigger for our country.So we are trying to get better results.

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