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Context Aware in Intermittently Connected Network Routing

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ABSTRACT: An intermittently connected network (ICN) is defined as a mobile network that uses cooperation between nodes to facilitate communication. This cooperation consists of nodes carrying messages from other nodes to help deliver them to their destinations. An ICN does not require an infrastructure and routing information is not retained by the nodes. While this may be a useful environment for message dissemination, it creates routing challenges. In particular, providing satisfactory delivery performance is difficult with no network infrastructure or routing information. In this paper, context aware techniques are used to improve the delivery probability in an ICN. The examined context aware techniques are environmental, historical and personal against early and popular ICN routing protocols. It is shown via extensive simulation that context aware employment in ICN routing methods increase the delivery probability by 15%.

KEYWORDS: Intermittently connected network; routing; context aware; delivery probability; environmental context aware; historical context aware; personal context aware.

I. INTRODUCTION

Wireless networks allow mobile users to communicate ubiquitously, and have become widespread in recent years. A wireless network can be organized in three ways. First, a fixed network infrastructure with access points can be employed. With this approach, mobile nodes communicate solely via these points. A drawback of this approach is that when a node moves from one access point to another, delay and packet loss may occur. Further, a node may move outside the range of the access points. The second approach is to form an ad hoc network to allow nodes to communicate. In an ad hoc network, each node has the ability to route a message to the destination without the existence of a fixed infrastructure. Nodes track each other by sending control messages when they move. This allows nodes to forward a message to its destination. However, maintaining node positions and routes can consume significant resources, particularly in dense environments. In addition, an ad hoc network is limited in size by the transmission ranges of the nodes. This size is typically much smaller than with a network based on access points. To overcome the limitation given above, an intermittently connected network (ICN) can be employed. In this case, nodes are able to route a message to the destination without keeping track of the movements of other nodes.

Intermittently connected networks (ICNs) have been the subject of much research activity because they allow node mobility without permanent connections between nodes. Although this offers great flexibility, it creates routing challenges. In fact, existing routing protocols for ad hoc networks are not applicable in this case because a route to other nodes may not exist. Thus, approaches to routing have been proposed for ICNs which assume that there is no path between a source and destination. These methods can be classified based on their choice of the next carrier of a message as opportunistic forwarding, prediction based, or social relationship based. With opportunistic forwarding, messages are forwarded to any encountered node. In predication based methods, an algorithm is used to predict which nodes have a higher probability of delivering a message to a destination. This is typically based on their contact history. Finally, social relationship based methods forward a message to encountered nodes that share a social relationship with the destination, for example, if both the destination and an encountered node attend the same school or college. The proposed ICN protocols include those in [1] and [2] for opportunistic forwarding, [3], [4] and [5] for predication based forwarding, and [6], [7], [8], [9], [10], [11], [12] and [13] for social relationship based forwarding. The delivery

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probability is defined as the ratio of the number of packets received by destination nodes to the number of packets sent by source nodes. This probability can be improved by disseminating more message copies in the network [1]. However, nodes in an ICN are rarely connected, and typically only for short durations. Further, they have limited buffer space and battery life. Thus, messages routing method in ICN environment needs to be carefully chosen. In such cases, context aware can improve the delivery probability by improving the routing decision. Based on the encountered node context, an informative decision is made to weather the message is forwarded.

The remainder of the paper is organized as follows. Section 3 presents the context aware in ICN. The message delivery probability with context aware is evaluated in Section 4. Finally, some conclusions are given in Section 5.

II. RELATED WORK

Epidemic [1], as the opportunistic forwarding method, is a routing protocol that uses opportunistic forwarding to send messages. Epidemic is simple since the messages are flooded.Flooding is defined as forwarding messages to every encountered node that may deliver the messages to the destination. Another opportunistic forwarding method is Spray and Wait [2] routing protocol. Spray and Wait protocol only forward a copy of a carried message to the first L encountered nodes. L can be determined based on many factors including the size of the environment. In order to solve the resource consumption problem with opportunistic forwarding methods, the probabilistic routing protocol (PRoPHET), a predication-based routing protocol, has been proposed [5]. As described in [5], the history of encountered nodes is buffered. To make a forwarding decision, the saved history is used to calculate the probability of meeting a node again. Nodes that are encountered frequently have a higher probability to meet again and older contacts are discarded over time. Messages are only forwarded when the delivery probability of an encountered node is higher than the current node which is the carrier of the message.

Status [8] is a social relationship-based routing protocol. With this protocol, when a node is encountered a message is forwarded based on two factors. First, if the encountered node has a status, it may receive a copy of the message. Having a status means that the encountered node is going to a point of interest (PoI).A PoI is expected to have many nodes located there, such as a shopping mall or a park. Second, a message is forwarded to an encountered node if this node lives in the neighbourhood of the destination node. Status removes the computational complexity that exists in PRoPHET. It also reduces the resource consumption that occurs in Epidemic. However, with no limited resource, epidemic has a higher delivery probability.

Research has focused on the context awareness for its promising performance [14], [15], [16], [17], [18], [19], [20], [21], [22], [23]. The context awareness brings benefits to many application including efficient routing, and secure communication [25]. The implementation of context awareness can be achieved by virtual sensors or physical sensing. In physical sensor, sensors are physically deployed to collect data in the deployed environment. Where virtual sensing deals with the context of data, such as email to reach the targeted awareness in the targeted environment. Both, physical and virtual methods have not been deeply researched in literature. Context awareness benefits for routing has only discussed in [22] and [23]. This research paper is a continuous effort to enrich the field with practical method for context awareness in the ICN routing. The proposed method here employs the physical and virtual data sensing [25] in ICN environment to improve routing based on context awareness. The improvement mainly targets the achievement of successful message routing in ICN environment.

III. CONTEXT AWARE IN ICN ROUTING

Context aware source take many forms including personal, environmental, networking, social, and historical data. Personal awareness can lead to identify a person activities and locations. Environmental gathered data can bring the surrounding weather conditions as a source of data that helps in network applications. Being aware of networking, it helps to identify how things are connected together. The method and spent time of interaction between things can be identified when social awareness is achieved. Finally, the awareness of a thing increases as its recorded past increases. These types of context aware can increase network performance and decrease security threats as main two applications [22]. This work mainly focuses on how the context awareness positively impacts the network performance.

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The impact of three context aware types against network performance is examined, namely, environmental, historical, and personal awareness. The network performance is determined by the successful routing of messages from the source node to the destination. This can be identified by delivery probability. Delivery probability is defined by the number of received messages to the number of sent messages.

The simplest form to improve network performance is to direct message to nodes that are most likely meet the destination shortly. This brings the need of the environmental awareness in its sensed temperature form. The idea is that the sensed temperature can help better route the messages. If the temperature is too low or too high, an encountered node most likely is moving soon from the current location, whereas a normal or good temperature suggests that the encountered node might stay for a while in its current location. Messages copies of a node is forwarded to those nodes that are in the move since their probability of meeting a destination node would increase. Figure 1 highlights the environmental context aware, where messages are only exchanged when the area temperature is abnormal since abnormal temperature indicates a quick movement of nodes from its current location to a new location with an increase of probability of meeting the destination node.

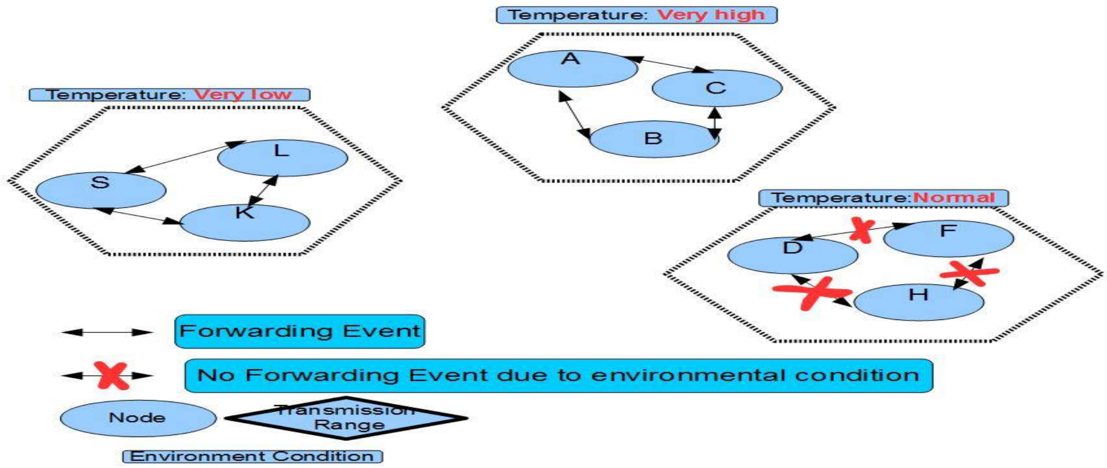

Fig.1: Context aware routing based on environmental condition.

Another form of useful awareness to routing in networking is the historical awareness. If the encountered node A had met many nodes in the previous t time, whereas node B only encountered few nodes in the past t time, this suggests that the node carrier of undelivered messages is supposed to pass its copies to node A. This is justified based on A is most likely to meet the destination node once A continue its behavior of meeting and traveling between nodes. Figure 2 present the historical awareness concept in ICN routing. It indicates that messages are forwarded to nodes that encountered a high number of nodes in the past.

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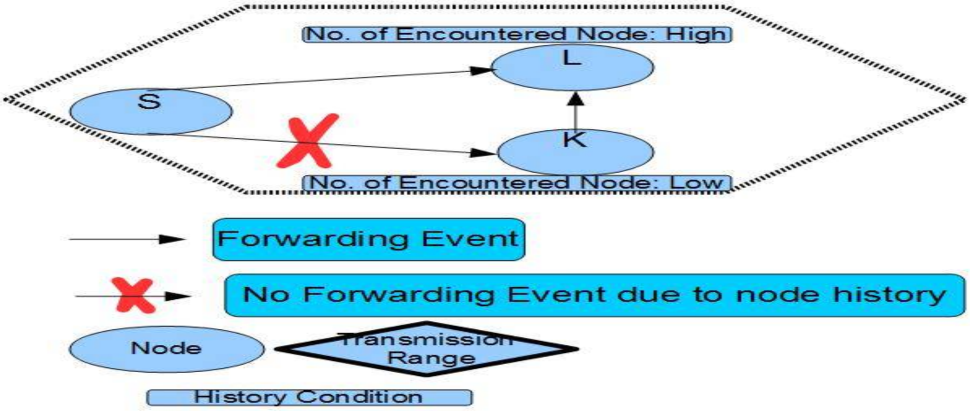

Fig.2: Context aware routing based on historical condition.

The third form of examined context aware form that is tested here is the personal one. One aspect of node personal aspects is its activities. If the encountered node activities similar to the destination node activities, this gives the carried message node an easy decision to pass a copy of the message to the encountered node. On the other hand, if the carried message node is aware that the encountered node has no similarity in its activities with the destination node, it would be most likely a waste of space and time to pass a copy of a message to the encountered node. It is shown in Figure 3 that messages are routed to the encountered nodes that share similar activities with the destination nodes. Next section examines the three form of context aware to measure their impact on routing in intermittently connected networks.

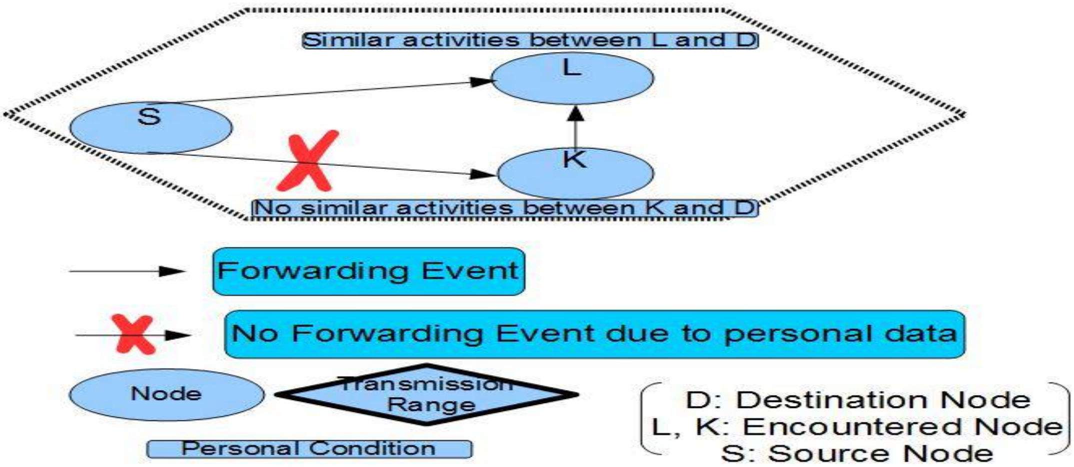

Fig.3: Context aware routing based on personal activities.

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IV. SIMULATION RESULTS

The section starts by explaining the details of the used co-simulator and the simulation settings followed by examining the performance of the proposed methods.

A. *Simulation Environment*

In this paper, ONE simulator [24] has been chosen and adapted to examine the impact of context aware in ICN environment. ONE is a discrete event simulation package. It combines movement modeling, routing, visualization and reporting. Mobility models determine node movement within the simulation environment. The random waypoint model (RWPM) is widely used and is based on random directions and speeds. However, this random node movement is unrealistic when mobile devices are carried by humans. It is more pragmatic to assume that nodes move towards a specific destination, then another destination, and so on. These destinations are typically particular locations such as malls, restaurants or schools, and so are called points of interest (PoI). The more realistic shortest path movement model (SPMM) has nodes moving towards particular locations, and so is employed here.

The simulation parameters employed here are carried out based on the realistic environment described in [25] where Helsinki City Scenario (HCS) model is used. The scenario has nodes moving in a part of the downtown Helsinki area. With HCS, node mobility is based on simulating 80 mobile users moving by foot, 30 by car, and 6 by trams in the streets of downtown Helsinki. Each node represents a user moving with realistic speed along the shortest paths between different points of interest (POIs) and random locations. The trams follow real tram routes in Helsinki. The simulation area is designed to be 4500×3400 m^2 size. The simulation environment parameters are summarized in Table I.

Table I: Simulation Environment Parameters

Parameter	Value
Transmit Rate	250 KBps
Transmit Range	50 m
Message Size	50-150 KB

B. *Performance Results*

In this section, simulation experiments are conducted to examine the performance of the three proposed methods against two early protocols in ICN, namely epidemic and spray and wait routing protocol.

The three proposed context aware techniques are first examined against epidemic routing protocol performance. Particularly, the delivery probability with epidemic is examined twice, with and without context aware techniques. Figure 4 shows that epidemic delivery probability improves by 10% when environmental context aware is employed. This shows the importance of the environmental context aware in the improvement of ICN routing protocols performance. The only added complexity to the routing method when environmental context aware is employed is attaching a sensor to the nodes for temperature sensing compared to routing messages without environmental context aware. Figure 5 shows that the delivery probability can be further improved when the historical context aware is employed. The improvement in delivery probability is by 13% when historical context aware is employed. In the historical context aware the only added requirement is to memorize the number of encountered nodes in the past. Finally, the personal context aware reports the highest impact on delivery probability compared to routing with epidemic with no context awareness. The improvement is shown in Figure 6 by 15% where is the only added requirement for the protocol is to profile network nodes activities for later routing decisions.

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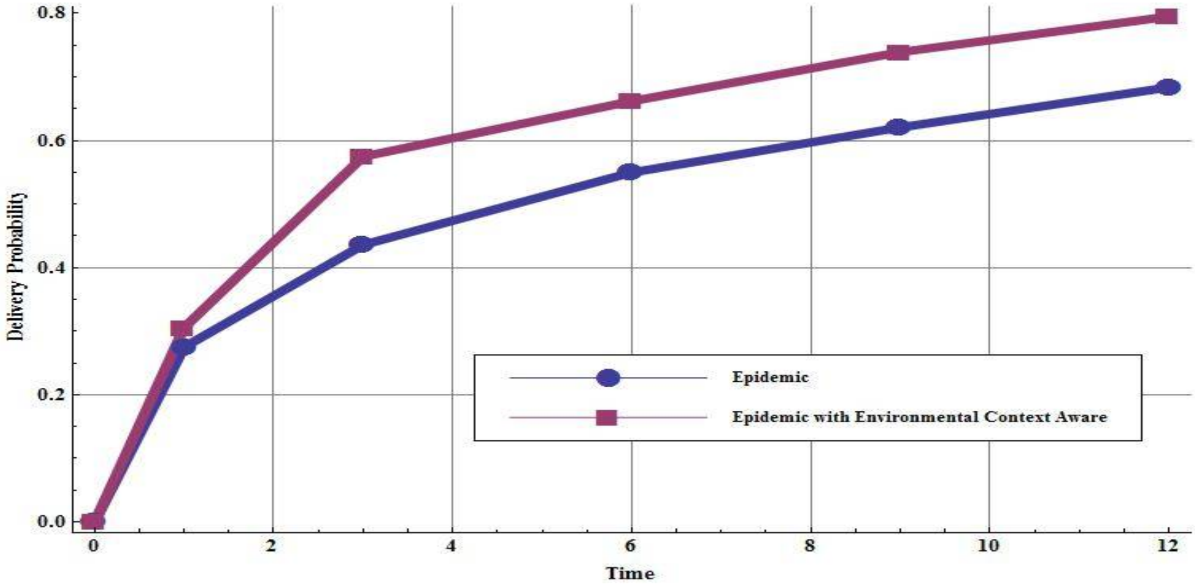

Fig.4: The delivery probability of epidemic routing method with and without envireonmental context aware

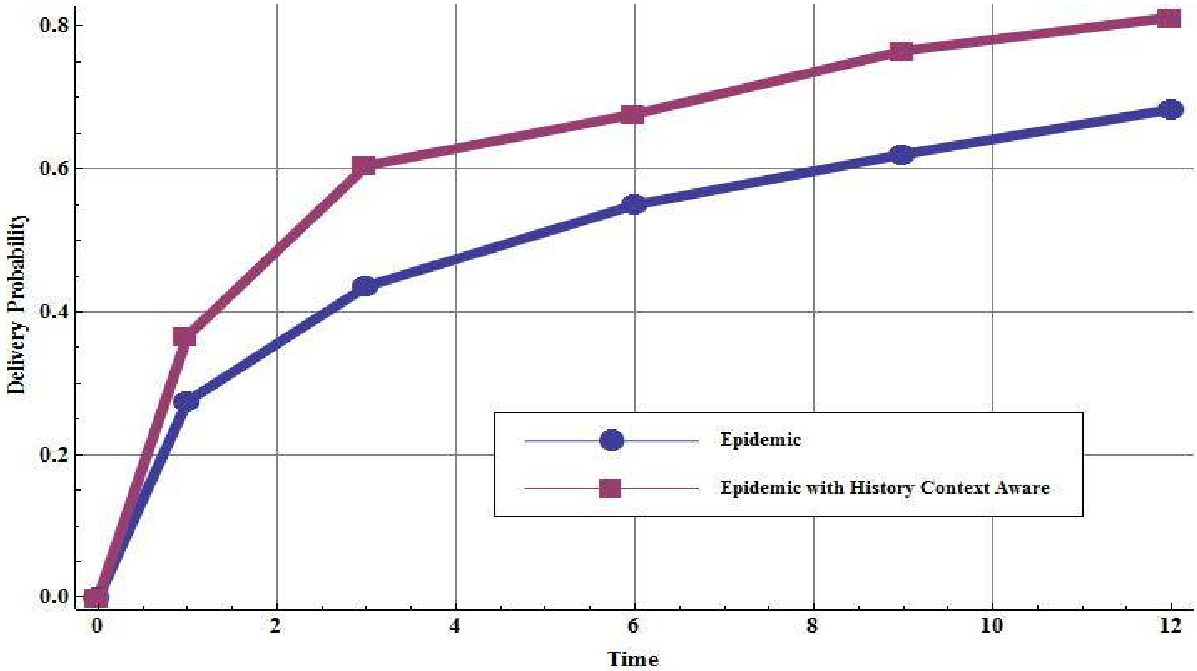

Fig.5: The delivery probability of epidemic routing method with and without historical context aware.

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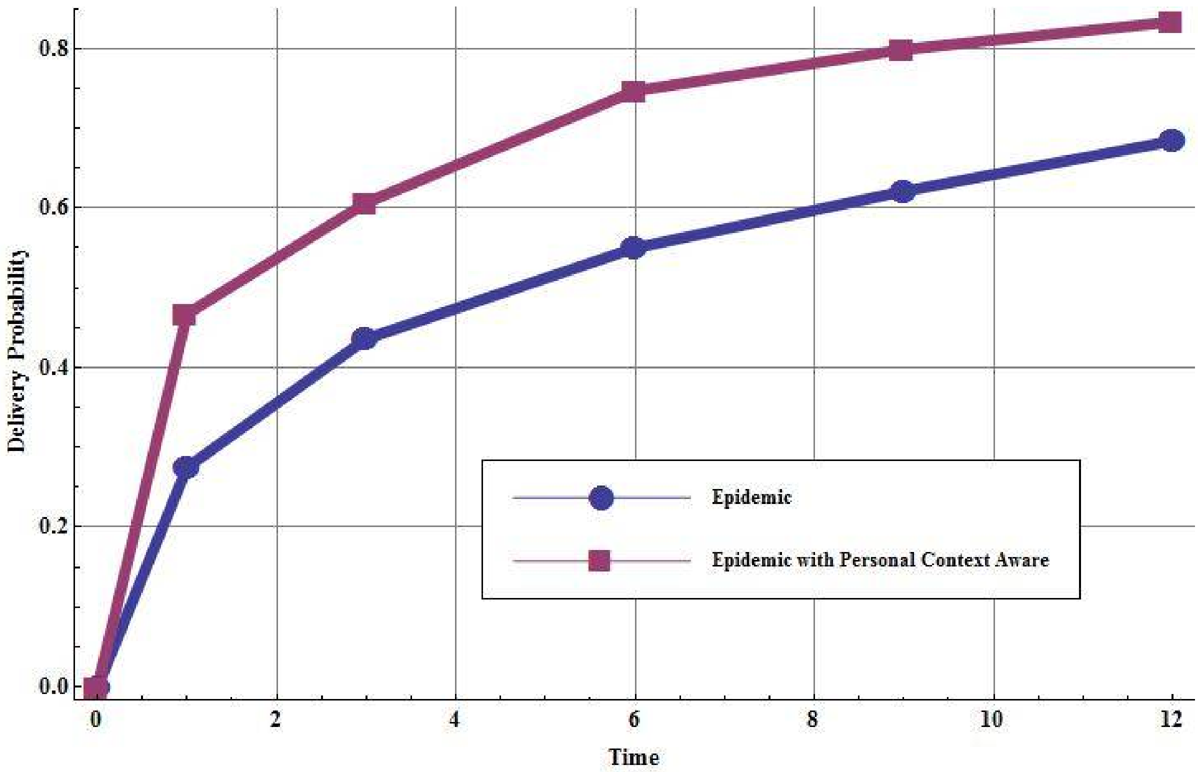

Fig.6: The delivery probability of epidemic routing method with and without personal context aware.

Spray and wait routing protocol is a popular ICN protocol for its reported good performance [2]. Context aware impact is also examined here on ICN routing performance against spray and waits routing protocol. First, environmental context aware improves the delivery probability by 8% as shown in Figure 7. Where Figure 8 shows that historical context aware improve spray and wait routing by 9%. Finally, Figure 9 reports 10% improvement in delivery probability in spray and wait when personal context aware is employed compared to spray and wait without context awareness.

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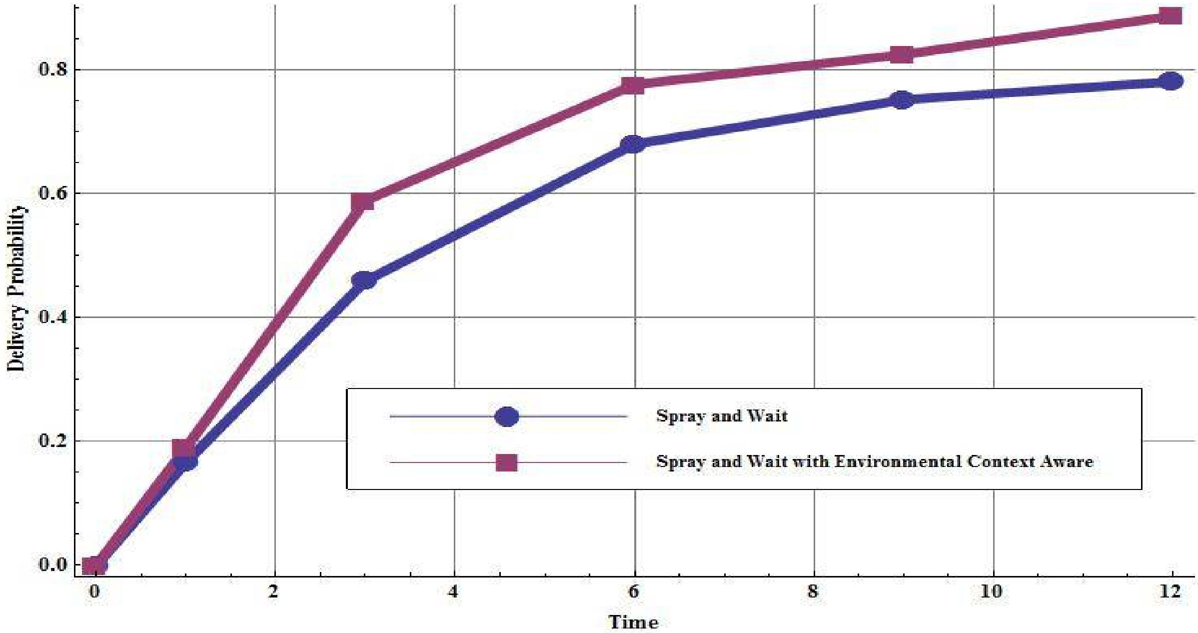

Fig.7: The delivery probability of Spray and wait routing method with and without environmental context aware.

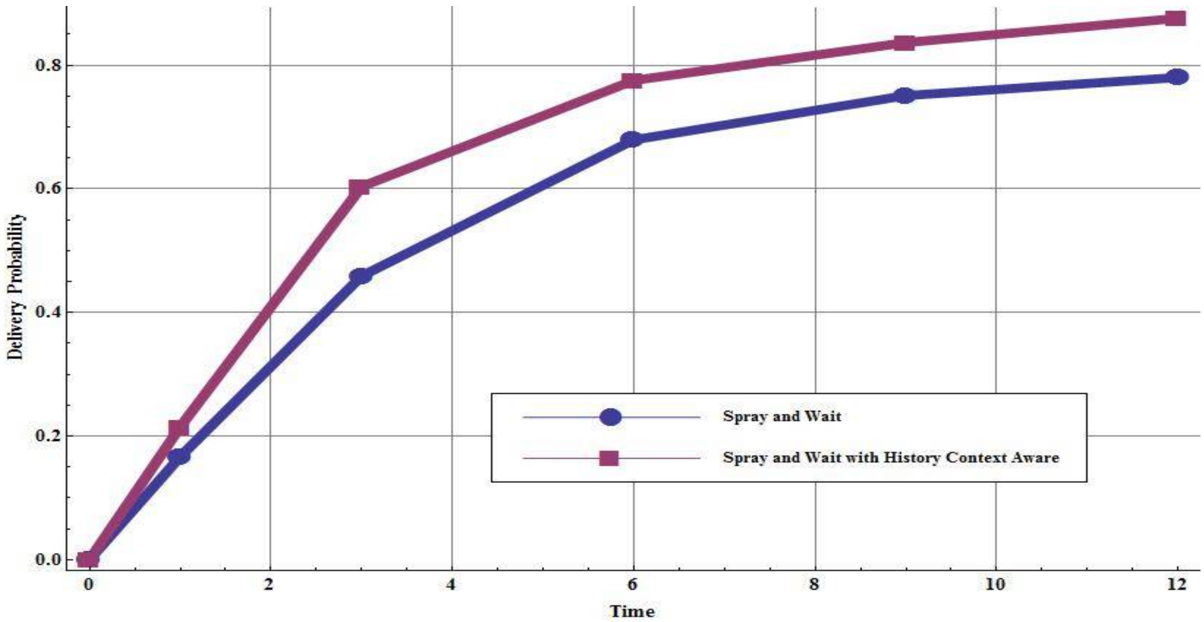

Fig.8: The delivery probability of Spray and wait routing method with and without historical context aware.

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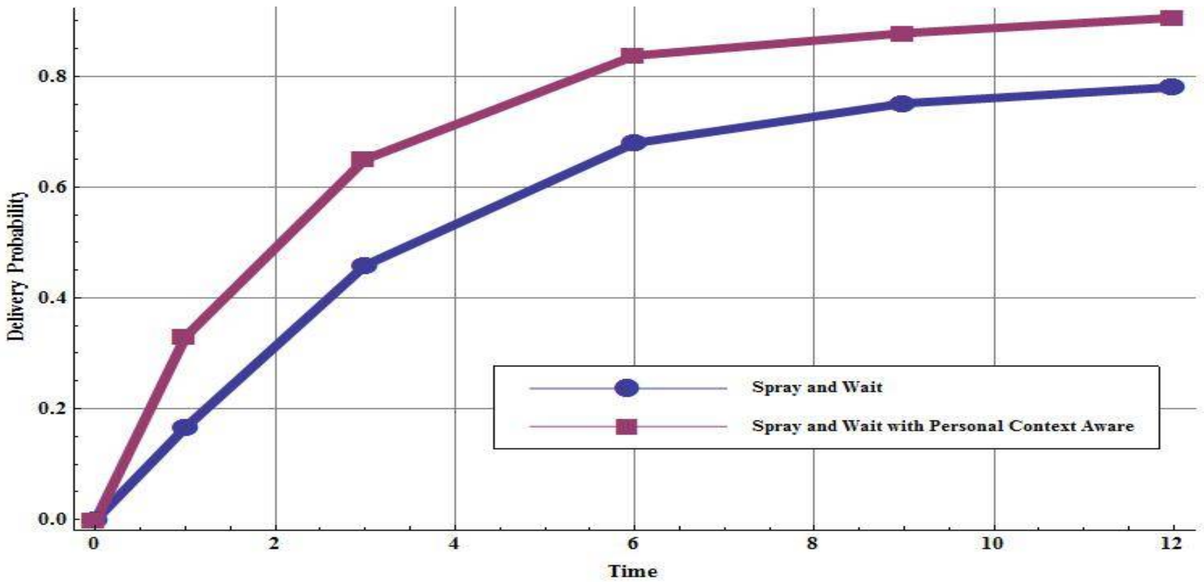

Fig.9: The delivery probability of Spray and wait routing method with and without personal context aware.

The above figures prove the positive impact of context awareness in ICN routing protocols. Particularly, the delivery probability of ICN routing protocols increases as context aware technique is employed. The impact of the context aware technique on the delivery probability differs slightly from one technique to other based on the usefulness of the collected data. However, the three context aware techniques all share being able to improve the delivery probability of ICN routing protocols. Note that although spray and wait protocol was reported to have a high delivery probability compared to epidemic [2], context aware techniques were able to benefit both routing protocol despite their original performance.

V. CONCLUSION

This paper presents the impact of context aware in ICN routing protocols. Three techniques of context aware is discussed, namely, environmental, historical and personal context aware. The three techniques show the improvement of ICN routing protocols when they are employed. The improvement of ICN routing protocol when context aware is employed is reported between 8% and 15%.

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