

Packet Loss Avoidance in Content Centric Mobile Adhoc Networks

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Abstract— As a result of the fast growing mobile technologies and application types, user generated contents are dominating contents on Internet. New Internet architectures are emerging because of the lack of suitability of TCP/IP Internet architecture to serve the recent traffic types and content centric network is one of such proposed architecture. This architecture was proposed for wire based Internet and lacks features to directly apply it on wireless and mobile ad-hoc networks. In mobile ad-hoc networks, due to mobility of intermediate nodes, connection between two remote nodes fails frequently bringing packet loss problem and a need to avoid it. Packet loss causes communication delay, throughput degradation and congestion and may even make the network unusable. This paper proposes a new CCN scheme with packet loss avoidance built into it. Simulation results show that our proposed scheme performs very well in a dense network with high mobility.

Keywords— CCN; link failure; link recovery; mobile ad-hoc network; packet loss avoidance

I. INTRODUCTION

The Internet has been evolving and growing rapidly in terms of types of service provision and amount of data exchanged. This tendency will continue in the future depending on the changing needs of the time. In its initial stage, function of Internet was to enable sharing of files between two endpoint entities such as server-client relationship. With development of technologies and infrastructures, current Internet follows this basis and tries to allow a diversity of communication to enable up-to-date and up-coming services. It is no more just a means of information sharing but rather it has become the core of daily life of people and business around the globe. Currently, the communication trend is showing paradigm shift from traditional client-server architecture towards creation, dissemination and acquisition of content itself which springs up everywhere. Therefore, most of current Internet communications are centered on content without caring much where it is physically located [1]. But the communication technology in use today functions mainly based on where the data is located. To enable content based communications, current services are using application specific mechanisms like Content Delivery Network (CDN), Peer to Peer networks and HTTP proxies, positioned on top of the network stack.

In recent years more and more people are accessing Internet from their mobile phones and tablets since mobile technology is growing rapidly and becoming more comfortable to use. Hence mobility and wireless issues should be considered for any new proposed Internet architectures to be viable. But

content centric networking (CCN) [1], the most widely cited architecture for named contents and called as typical CCN in this paper, was initially implemented with consideration of wired Internet properties. In order to apply it on wireless networks, CCN requires some modifications to cater with the demands of mobile wireless networks, like congestion, contention, low battery power and small memory size [2]. Another behavior of mobile ad-hoc networks is rapid change of topology and mobility of communicating entities from location to location. The use of wireless medium has advantages and disadvantages over wired for implementation of CCN. From the advantages of wireless medium is its broadcast nature, which can be used for Interest aggregation. A node may stop or defer sending interest packet upon overhearing that its neighbor is requesting same interest packet and retrieve the data when the requesting node receives the requested data. The downside of wireless environment is the need to have packet loss avoidance and link failure recovery schemes because of node mobility which complicates implementation of CCN on MANETs.

The mobility of nodes in MANETs means that there is frequent link disconnection between neighboring nodes. This link failure affects all preceding nodes whose path to content server includes the disconnected node and causes loss of packets. If packet loss problem is not addressed fast, it might cause communication delay, throughput degradation and congestion. Solution for the packet loss problem varies depending on the type of routing protocol used to populate FIB table entries, namely reactive or proactive routing protocols. In reactive protocol case, the client nodes broadcast their Interest packets whenever needed whereas in the proactive case content server periodically advertises its content and intermediate nodes broadcast advertisements and available routes in their table to neighboring nodes. The later protocol is more advantageous in a network where node mobility occurs in some parts of the network. In reactive protocols, the possibility of packet loss might be minimized by utilizing multiple routes while broadcasting the interest packets and sending the requested content through all the paths that the interest packet used to reach the content server. But the use of several simultaneous routes will increase congestion on the network and degrade throughput. The usage of broadcast and multiple paths might be optimized using overhearing and defer time, as used by listen first broadcast later IP based MANET protocol [3]. However in CCN proactive protocol based FIB population, link is recovered when the next periodic advertisement is propagated to all the nodes in the network. Waiting for the next

periodic advertisement cycle to recover link failure increases transmission delay and degrades throughput.

This paper addresses the problem of avoiding packet loss in CCN MANETs using pro-active routing protocol. It avoids interest and data packets loss using different methods, by considering special properties of CCN. It uses mix of pro-active and reactive techniques to prevent communication loss that may be interrupted because of movement of intermediate or client nodes. The packet avoidance is transparent to the source node and it is mostly performed by the node that detected link failure with its next hop.

The rest of the paper is organized as follows: section II introduces previous works on CCN application and link recovery schemes for IP based MANETs; section III describes the proposed packet loss avoidance scheme for pro-active routing based CCN MANETs; section IV will cover simulation result and analysis, comparing how the proposed scheme fares against CCN without link recovery scheme and section V covers conclusion and future work.

II. RELATED WORKS

A. CHANET

A Content centric fashion MANET (CHANET) [4] provides more features as it build on to the concept of a simple CCN. It uses broadcast packets, allowing for simplicity, availability and robustness. To face scalability issues and reduce collisions due to broadcasting, it takes advantage of overheard packets. Forwarding decisions are locally taken at each receiving node without any explicit signaling exchange with neighboring nodes. It indirectly implements traditional transport functions like sequence control and retransmissions requests by embedding acknowledgments in the Interest packets. It implements techniques to face mobility of consumers and providers. CHANET nodes can take the benefit of shared communication medium, so that broadcasted packets may be opportunistically received by more consumers simultaneously. But computing or updating distance tables by constant overhearing is not an efficient approach and our proposed scheme can avoid packet loss more efficiently in a network with mobile nodes during data communication phase by doing a controlled broadcasting of the packet.

B. IP MANET LINK RECOVERY SCHEMES

Solving link failure and packet loss problem in MANETs with dynamic topology is critical for effective communication and service provision. The cause of link failure might be movement of intermediate nodes, depletion of battery or system failure. This problem has been researched for many years and there are various kinds of schemes proposed to address it. Reactive and proactive MANET routing protocols address route maintenance in different ways.

In reactive routing protocols, path is established when required. Source node creates connection with its end point by sending RREQ to the network and uses this connection for data transmission. The easiest path maintenance scheme in reactive approach is for the source node to take care of tracking connectivity between end points. The source node re-transmits the lost packets when its preset timer expires. Since its timer

has expired, the source node assumes that the packet is lost and starts re-transmission. This further increases congestion on an already crowded network. The source node takes it a timer amount of time to recover the lost packets hence spending more time to recover lost packets. Another reactive approach for route maintenance is for the node that detected link disconnection to send RERR message to the source node and create new route and retransmit the data using the newly established path. The problem with this scheme is it takes long time to re-establish route and send data. This approach is used by DSR [5] and AODV [6]. Another variant of this scheme is for the node that detected the link to request new connection rather than sending RERR back to the source. This scheme saves time and decreases overhead on the network but still not optimum solution.

Multiple path creation is another scheme of route recovery. Ad-hoc on-demand multi-path distance vector routing protocol, AOMDV [7], is typical reactive routing protocol that uses multiple loop free and link-disjoint paths to re-establish failed connection. While creating initial path using RREQ and RREP, source and intermediate nodes keep record of alternative paths that are loop free and link disjoint, the former to avoid infinite loop while forwarding packets and the later to avoid using more than one links that connect at some point before reaching destination node. When one link fails, the nodes select alternative path to the destination.

In pro-active routing protocols, all nodes have topology information of the network prior to sending data requests. The data source sends periodic content advertisement and intermediate nodes forward it further on the network. One of the earliest proactive routing protocols is destination-sequenced distance vector (DSDV) protocol [8]. It is table-driven routing scheme for MANETs. Destination node generates even numbered sequence number to mark a path which is used to solve routing loop and indicate stale route. When a node detects its connection is broken, it increments its sequence number and sends it to its next hop node. The receiving node updates its routing table upon checking the sequence number value. In an improved version of DSDV, when a node detects link failure it broadcasts ROUTE-REQUEST and ROUTE-ACK messages to its one-hop neighbors to create a temporary link that will serve till the next periodic route advertisement. Another proactive routing protocol is optimized link state routing with reactive route recovery (OLSR-R³) [9]. OLSR is a pro-active routing protocol and is combined with reactive scheme to create hybrid routing protocol. It uses a reactive approach to maintain broken route. Using the hybrid scheme lowers transmission latency without suffering from frequent disconnection. When a node detects route failure, it broadcasts RREQ and the neighbors rebroadcast it if the link is not available in their routing tables. After the node receives RREP, it starts communication and uses the link until a better link by the next proactive periodic advertisement is established. But the problem with proactive protocols in MANET is it consumes too much energy by exchanging periodic advertisements among nodes. It is suitable for a MANET with no frequent topology change, since in highly dynamic MANET by the time that the end point nodes receive route updates it may occur that the topology may already have changed.

III. PROPOSED SCHEME

In this scheme, mobile nodes detect availability of neighboring nodes using periodic overhearing of their activities. If a neighboring node fails to forward periodic advertisement or it is inactive for some fixed time, the link between the two nodes is considered to be unavailable. The packet loss avoidance scheme begins when a connection between two nodes is detected to be broken this way.

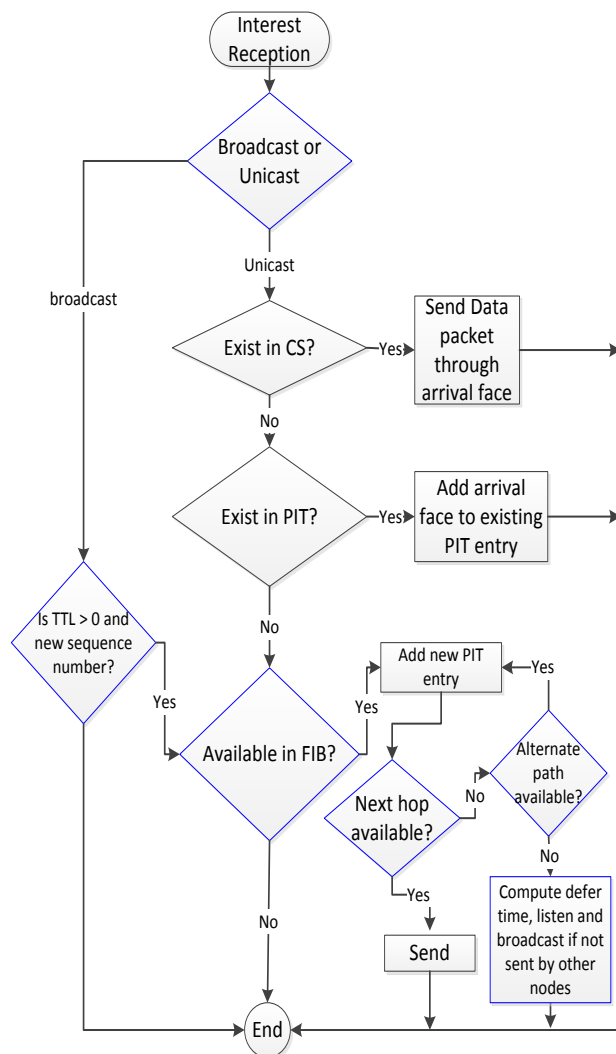


Fig 2 Interest Packet Processing in the proposed scheme

In the typical CCN, a node receiving an Interest packet searches its FIB table for next hop entry. The content provider sends the requested data by following the reverse path of the Interest packet used. If the packet is not received successfully, it will be dropped and the intermediate sender doesn't take any prior action to avoid occurrence of packet loss. The original node that requested the packet will have to wait for some timeout value to retransmit its requested interest packet. Flow chart of the proposed scheme's packet processing is shown in Figure 2 and Figure 3. As shown In Figure 2, Interest packet processing starts by checking whether the packet is broadcast or unicast. If it is broadcast, it checks its TTL value and

sequence number and passes it to the typical CCN's function of searching entry in FIB table, otherwise it will drop it. If a next hop entry is available for the content and there is no cached content, it sends the packet using the best available route available. If there is no next hop node, it calculates differ time, listen its neighbors until timer expires and broadcasts it only if no neighbor already sent similar packet. The unicast packet processing follows similar procedure, except that it doesn't need to check TTL value. Figure 3 shows data packet processing in our scheme. The additional features in this scheme are that before deciding to send the data to its next hop node, the current node makes sure its neighbor node is available. If it is available it proceeds similar to the typical CCN, otherwise it broadcasts the packet setting TTL value of two and sequence number.

The following section explains the proposed scheme for recovering Interest and Data packet loss because of link failure.

A. Interest Packet Loss Avoidance

During content advertisement, intermediate nodes may receive multiple paths that lead to the source node. In this scheme all nodes keep record of the multiple paths in their FIB tables sorted in terms of hop count and use them to find alternative means to transmit packets. Other metrics instead of hop count may be used. The next two sections describe the two packet loss avoidance options for Interest packet recovery.

1) Alternative Path Selection: When an Interest packet arrives on a node, it first checks its cache. If the content is not available in its cache the node then searches in its FIB table for the next hop, with least hop count to destination, and forwards it if it is available. But if the next hop node is marked as unreachable, the node searches its FIB table again and uses the next best available route to the destination.

2) Broadcast: If all alternative next hop nodes are unavailable or there is no alternative path towards the content server, then the node broadcasts the Interest packet with fixed TTL value to prevent flooding. TTL value of two was arbitrarily chosen for this paper's implementation. Because of frequent mobility of nodes and change of topology in wireless networks, new nodes that lie in a path towards the content server but with no path entry in their FIB table may arrive in the vicinity of the current node. This broadcast scheme uses the newly arriving nodes as a bridge to reach nodes in the path to destination server with an existing entry in their FIB table. The nodes that received the broadcast packet first check sequence number and TTL value of the packet. If the TTL value is not zero, the same content request with similar sequence number was not received and the requested content isn't available in its content store, then the receiving node calculates defer time and starts overhearing. After the defer time expired and confirming that no other node has forwarded the same packet, it decrements its TTL value, checks its routing table and forwards it to next hop if available or broadcasts it otherwise. Sequence number on data packet is used so that any duplicate Interest packets that arrive on a single node are not unnecessarily forwarded more than once.

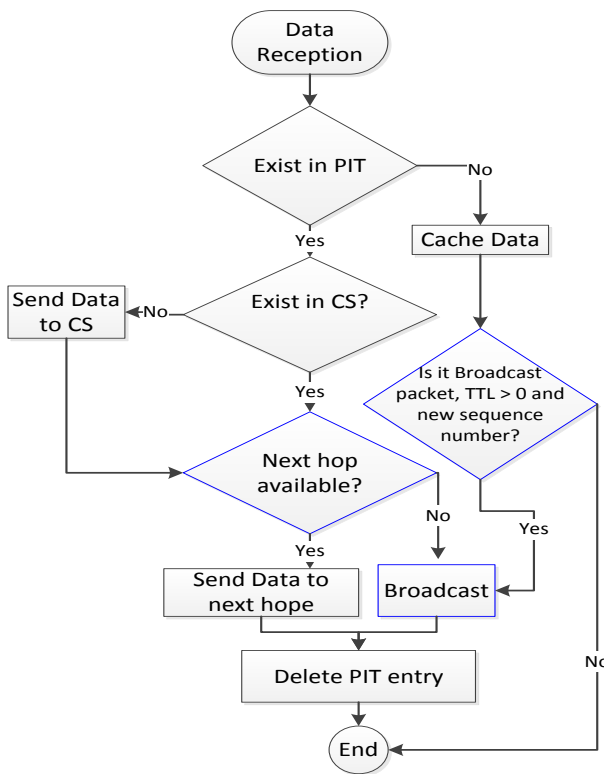


Fig 3 Data Packet Processing in the proposed scheme

B. Data Packe Loss Avoidance

In typical CCN when a node receives data packet, it looks up the next hop node in its pending Interest table (PIT) and forwards it. But if the next hop node is unreachable and the link is broken, the node drops the packet and the client will have to wait for its timer to expire before sending its Interest request again.

After detection of link failure that causes data loss, our proposed scheme uses broadcast to reach nodes that may have pending Interest with same content name. Newly arriving nodes or other intermediate nodes will further broadcast the data packet to their neighboring nodes, increasing the probability of reaching nodes that lie in the path of the original Interest request. Similar to Interest packet, the data broadcast packet also has sequence number to prevent duplicate broadcast and fixed TTL value to minimize flooding in the network.

For this paper's implementation, TTL value was randomly chosen to be two. A node that receives the broadcast data packet caches the data and checks its PIT table. If there is pending request, it forwards it to next hop node otherwise broadcasts it, provided that the packet's TTL value is not zero and a packet with same sequence number was not already broadcast earlier.

The proposed scheme ensures before transmission that the link with its next hop node is functioning before using it and finds an alternative means. The proposed scheme addresses two mobility scenarios that cause packet loss:

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Num. of nodes	20
Num. of contents	100
Prefix announcement interval	1, 7, 15, 30 (Default: 15)
Cache replacement policy	LRU(Least Recently Used)
Traffic generation pattern	CBR (1500bytes/sec)
Node mobility model	Random waypoint
Node speed(m/s)	0, 5, 10, 20
Simulation field Size	500m x 500m
Transmission range	100m
Wireless characteristic	802.11b (11Mbps)
Simulation Time	300 sec

The first scenario is when an intermediate node moves from its previous location. This causes both Interest and Data packet loss. The proposed scheme avoids packet loss by first using alternative path and broadcast. In the case of Data packet, the scheme proposes broadcast since the Data can only follow the path used by its associated Interest packet. Even if the data is not received by the next node in the path of Interest request, it will be cached in the nodes that received the data broadcast and will delivered faster next time it is requested by the client node.

The second scenario is movement of client node. Movement of the client node that requested the data affects delivery of data. The client will receive the data using broadcast if it has not moved more than two hops away from its preceding node. Even if it is more than two hops away, the next time it requests the data, it will receive it from nearby node since the broadcasted data packet will be cached by the nodes in the data broadcast.

IV. PERFORMANCE EVALUATION

A. Simulation Environment

We used content centric network as defined by [1] using proactive routing update to populate its FIB table entry and implemented using OPNET simulator. Our scheme was also implemented using OPNET and compared it with the typical CCN. We compared typical CCN and our proposed scheme using four parameters, namely delivery ratio, round trip time, cache hit ratio and prefix announcement interval time variation. We used 15 seconds as an interval period for prefix announcement by the content server for the first three parameters. Table1 shows the other parameters used in the simulation environment.

B. Result Analysis

Fig 4 depicts successful delivery ratio of packets measured by varying node mobility speed from 0 to 20 m/s. Delivery ratio is a ratio of how much of the packets requested by a client node are delivered successfully. As shown in Fig 4, the proposed scheme outperforms the typical CCN. Initially at stable state, the typical CCN performs slightly better than our

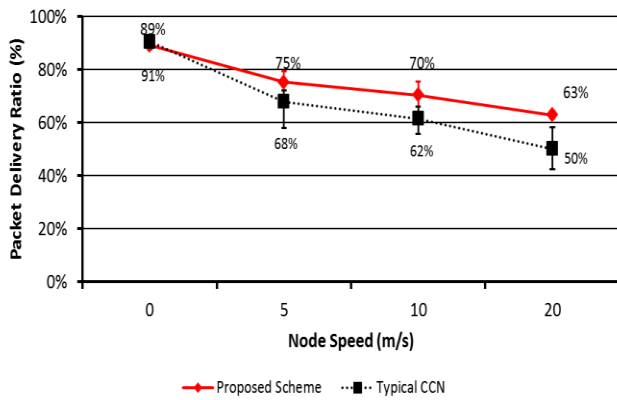


Figure 4. Packet Delivery Ratio varying Node Speed

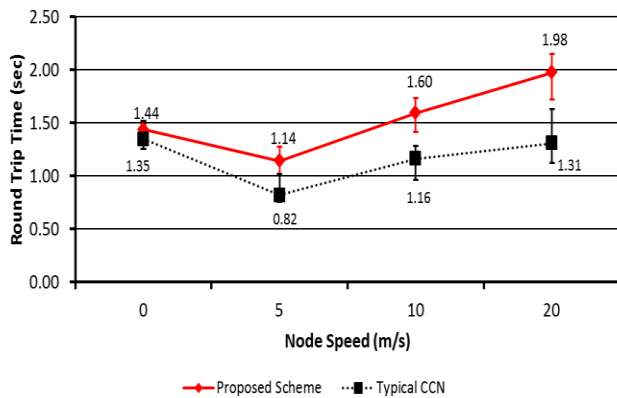


Figure 5. Round Trip Time varying Node Speed

scheme. The reason for that slight underperformance is the usage of overhearing causes false positive assumption of link breakage even if the nodes are stable and the possibility of link failure is low. That causes a node to use less optimal alternative path or broadcast even if the best path is available. But when we increase node mobility speed, the advantage our scheme has over typical CCN becomes obvious and grows to as much as 13% difference at 20m/s speed.

The second parameter used to examine the proposed scheme is round trip time (RTT). The RTT is calculated only for the successfully delivered user requested data. It is an average time of all successfully served requests. Data requests that were not delivered are not included in the average RTT value. As shown in fig 5, the proposed scheme consistently has higher RTT value than typical CCN. The proposed scheme has higher RTT value since, at the event of link failure, the Data or Interest packets are sent through alternate paths broadcast that generally take more time than the original path. In the case of typical CCN, the lost Interest or Data packets are not included in the average RTT calculation since they are not successfully delivered to the user. The more speed the nodes have the better our proposed scheme performs, since there is more link failure in higher speed.

Figures 6 show the performance metric in terms of average cache hit. Consumers are randomly selected among the mobile nodes in the simulated grid and the speed of the nodes was

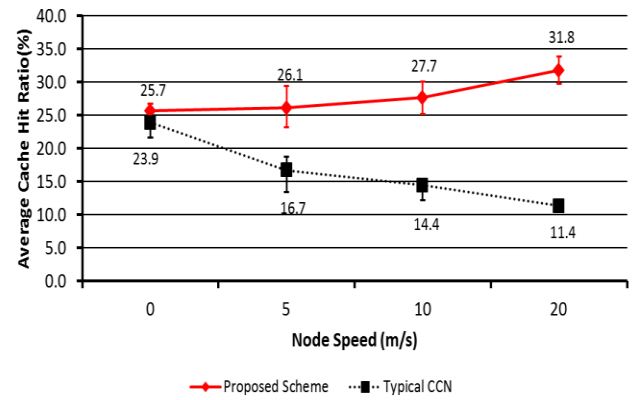


Figure 6. Average Cache Hit Ratio varying Node Speed

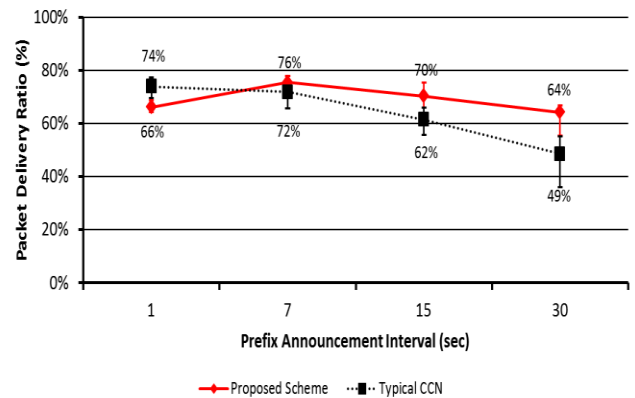


Figure 7. Packet delivery ratio with packet announcement period variation

kept between 0 to 20 m/sec increasing in linear fashion. Advantage of the proposed scheme becomes less visible due to effect of overhearing and the subsequent use of alternate paths between the nodes when the network is stable. Caching performance difference between our proposed scheme and typical CCN becomes more visible with increase of speed of nodes, going as much as 20% improvement. With increasing speed of the cache hit performance, our approach starts to increase whereas in typical CCN the performance degrades. When the nodes in a network increase their speed, there will be more link failure and hence more packet loss in the network.

Figure 7 shows packet delivery ratio by varying content provider's prefix announcement rate. We started with a constant node mobility speed of 10 m/sec, a prefix announcement rate of 1 advertisement per 1 second and increased it linearly up to 1 advertisement per 30 seconds. The result in the graph shows that under heavy prefix advertisement scenario of 1 advertisement per 1 second the typical CCN performs better by sacrificing the network performance due to heavy traffic being generated by the content announcements. As we lower down the advertisement interval gradually, we can clearly see that our approach starts to perform better due to the fact that in a high mobility environment low content announcements result in stale FIB

entries that don't reflect the recent network setup. Hence typical CCN fails to forward packets successfully since it is dependent on this stale FIB table. But our proposed scheme recovers the failed links and makes use of the newly arriving nodes to forward packets to destination.

V. CONCLUSION

In this paper, we developed a new content-centric link recovery scheme that improves content retrieval, caching, and delivery in IEEE 802.11 MANETs. The typical CCN implementation waits for the client node that sent the interest packet to detect packet loss, which increases transmission delay and degrades throughput on the network. Our proposal is designed to cope with the wireless link impairments and highly dynamic topologies and to limit the signaling overhead. Our proposed scheme recovers lost packets by detecting the disconnected node and trying alternative means to successfully transmit data or interest packets. The link recovery is transparent to the consumer and is performed without using any additional control messages, which add overhead on the network. As a future work, we plan to assess the benefit of backtracking to preceding node after unsuccessful attempt of recovering links from the current node. Simulation results show that the proposed scheme has great benefits offered in terms of high throughput, reduced latency and control overhead compared to typical CCN as proposed for wired networks.

ACKNOWLEDGMENT

This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency" (NIPA-2012-(C1090-1221-0011))

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