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MOBILE ADHOC NETWORKS CACHING MECHANISMS : A SURVEY

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Abstract-- MANET is an attractive solution in many real world applications in the personal, civilian and military fields without need of fixed infrastructure. Here in MANET ,the infrastructure is changing continuously. Ensuring security in Mobile ad hoc networks (MANET) is very crucial Adhoc Network security is different from traditional network security.Moreover MANET can be extended to have communication with Internet and other wireless networks through gateways. However, data access applications that depend on MANETs suffer from the problems caused by restricted energy supplies and mobility. The MANET is more vulnerable to be attacked than wired network. These vulnerabilities are environment of the MANET structure that cannot be removed. As a result, attacks with malicious intent have been and will be devised to develop these vulnerabilities and to cripple the MANET operation .Caching has been widely used in wireless networks to cope with such problems and ensure data availability and data access performance. The essence of the literature is that caching strategies improve performance of MANET in terms of data dissemination and availability. In this paper the status of research on caching mechanisms in MANET including cooperative caching, cache invalidation mechanisms, routing cache, transparent caching mechanism, caching database for MANET, cache sharing interface, cache timeout is reviewed and analyzed.. In this paper we have surveyed the various issues related with MANET and data availability and performance in MANETS.

Index Terms – Mobile Ad Hoc Network, cooperative caching, caching strategies, cache invalidation

I. INTRODUCTION

Mobile Ad Hoc Network (MANET) became a ubiquitous network as it is collection of nodes configured automatically without fixed infrastructure.Such networks are handy when infrastructure is destroyed or not available or costly. These networks exhibit frequent topology change besides frequent host movement as shown in Figure 1. MANET does not need cellular infrastructure. However, it uses multi-hop wireless links where data is routed through intermediate nodes. Each node acts as transmitter and receiver. In many real world scenarios MANETs are preferred as they do not need backbone infrastructure, easy to deploy and best used when infrastructure is impractical or missing. MANET can be used in many applications. For instance, in personal area network, wrist watch, ear phone, laptop, and cell phone can participate in network. In

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military environments planes, tanks and soldiers can avail MANET facility. In civilian environments MANET can be used in small aircrafts, boats, sport stadiums, meeting rooms, and taxi cab networks. In emergency operations MANET can be used for search and rescue, fire fighting and policing. There are many challenges in mobile environments such as limited resources, limitations imposed by mobility, and limitations of wireless networks. Wireless network limitations include packet loss, broadcast nature, constrained bandwidth, frequent partitions or disconnections, and variable capacity links. The limitations imposed by mobility include dynamically changing topologies, use of applications that lack mobility awareness. The important limitations of the mobile computer .include limited capabilities and short battery lifetime. Especially the mobility nature of nodes in MANET needs new applications and adaptations in Application layer of protocol stack, congestion and flow control in Transport layer, addressing and routing in Network layer, media access and handoff in Link layer and transmission errors and interference in Physical layer.

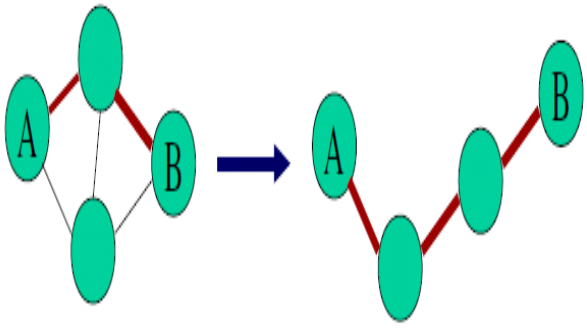

Figure 1 – Illustrates mobility and topology change in MANET [1]

This paper focuses on caching mechanism in MANET that can leverage data availability and improvement of performance. Many cooperative caching mechanisms for MANET were found in literature [5], [6], [7], [8], [9], and [10]. Cache invalidation strategies are explored in [2], [3] and [4]. Caching is also used for routing purposes. Many researches focused on the routing issues solved through caching [11], [22], [23], [27], [30], [31]. Client cache for solving inconsistency problems were explored in [12]. Cache timeouts and backup routes have their role to play in MANET performance [14]. There are caching alternatives explored in [15] and caching is also used for storing queries and responses in the form of a database [16], [17] and [32]. Transparent cache based mechanisms were explored in [13] and [17]. Reclaim based caching policies were explored with DSR and other protocols in MANETs [18]-[29], [33] The remainder of the paper is structured as follows. Section II reviews cooperative caching mechanism in MANET. Section III reviews the cache invalidation strategies in MANET. Section IV provides other caching mechanisms in MANET. Section V provides Comparative Observations Of Caching Mechanisms while section VI concludes the paper.

II.COOPERATIVE CACHING MECHANISMS IN MANET

MANETs provide an attractive solution in emergency situations. This communication network can be extended with other networks like Internet. This section throws light into the data access efficiency in MANETs through cooperative caching. Du (2005) [5] proposed

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and implemented a new cooperative caching scheme for MANET communications. The scheme is named "COOP" which discovers sources of data that can incur less communication cost. It gets rid of caching duplications as much as possible and improves data availability and efficiency. The experiments are made in terms of data availability, energy efficiency, and time efficiency. Miranda and Leggio (2005) [6] focused on replication of data in many nodes so as to improve performance. Their algorithm named PCache combines latency constraints with probabilistic approach for efficient cooperative caching. This approach allows a node to have data collected from other node such as one hop neighbor in a decentralized fashion.

Ma et al. (2010) [7] present a cooperative cache-based content dissemination framework (CCCDF) between two nodes to have cooperative caching for efficient content delivery. They provided two strategies such as optimal and max-min. The former takes care of content delivery efficiency while the latter takes care of fairness. Figure 5 shows performance of the algorithms when compared with existing strategies. As can be seen in Figure 5, it is evident that CCCDF provides highest performance when cache size is considered 6. Kuppusamy and Kalaavathi (2012) [8] focused on data consistency and data availability problems in MANET. To achieve the dual purpose, they proposed two approaches namely Cluster Based Data Consistency (CBDC) and Adaptive Push and Pull Algorithm for Clusters respectively. In order to achieve this it follows specific cluster head formation three kinds of nodes as shown in Figure 2.

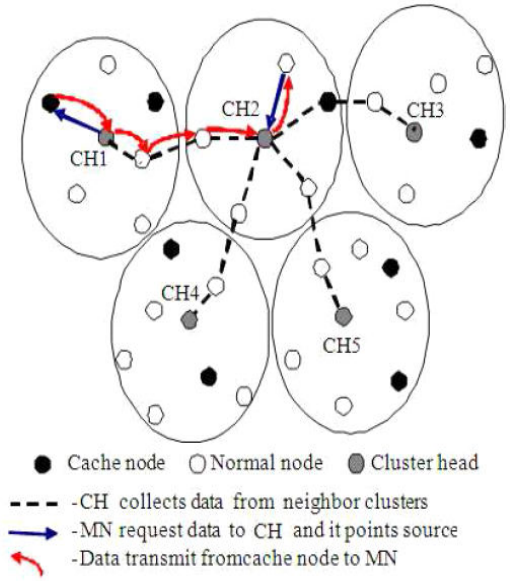

Figure 2 – MANET with cooperative caching [8]

The CBDC model satisfies many cache consistency requirements such as data update delay, consistency control and consistency level. The experiments on the pull and push models for cooperative data caching revealed that the solution is capable of reducing latency and overhead besides improving energy efficiency. Huang et al. [9] focused on cooperative caching using selective push algorithm. Many existing algorithms that is stateless in nature lack scalability and cost-effectiveness. They proposed a cache consistency mechanism known as Greedy Walk-based Selective Push (GWSP) where a node maintains Time to Refresh value and query rate along with cache copy. When

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compared with pull model with dynamic TTR algorithm it exhibits higher performance in terms of traffic overhead (41% saved) and query latency (85% saved). The algorithm achieves it using selective push by performing data updates in select nodes. Gonzalez-Cañete and Casilari [10] from University of Malaga studied the impact of mobility model in cooperative caching mechanism in MANET. They proposed a caching scheme that maintains local cache in every node and redirect cache for redirecting decisions. They also used interception caching for reducing latency where node takes decisions to forward requested data from cache.

III. CACHE INVALIDATION TECHNIQUES IN MANET

Lim et al. (2007) [2] focused on Internet based MANET named IMANET where cache invalidation can improve performance. They explored pull and push models as cache invalidation strategies. The proposed solution includes a GPS based connectivity estimation to know node connectivity and then it uses a pull-based approach and two push based strategies such as Modified Time Stamp (MTS) and MTS with Updated Invalidation Report (UIR).With these strategies in place, MANET achieves low overhead in terms of communication, low query latency and high throughput. In 2011, Fatima and Khader [3] proposed a hybrid cache invalidation strategy in MANET. This strategy is known as Extended Adaptive TTL which is based on TTL. The strategy is as shown in Figure 3.

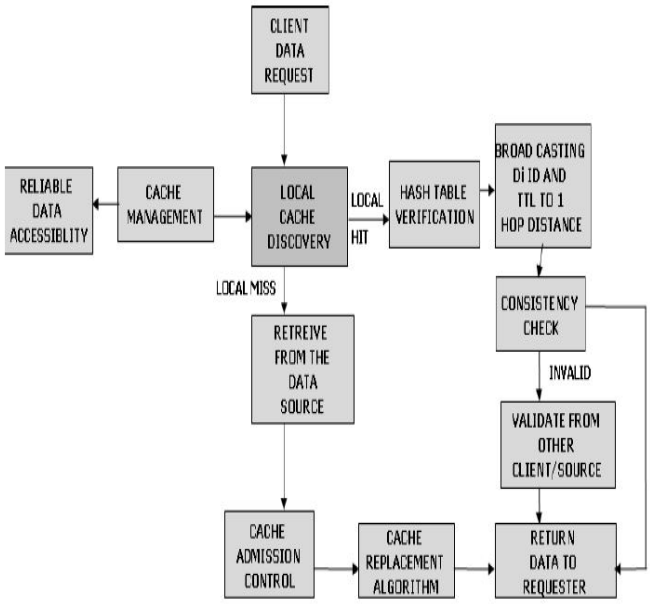

Figure 3 – Illustrates hybrid approach for cache invalidation [3]

As per the strategy, every node in MANET maintains a hash table for making cache invalidation decisions. It is a phased approach. In the first phase, when a data request is made by a node, the current node's hash table in verified. If it is found, TTL and T_c are taken from the hash table. Based on the TTL value it makes decision whether to move to next phase where local cache is verified. If the data found it is used otherwise data is obtained from nearest cache node followed by recalculation of TTL of node as NEW TTL = $T_{req} - T_c$. In the third phase, when local copy is in localized cache intermediary cache node, Tc is updated in hash table. Then the cache node broadcasts Tc, TTL and id to one hop neighbors [3]. Similar kind of cache invalidation strategy based on TTL can be found in [4].

IV. OTHER CACHING MECHANIMS IN MANET

A. Caching Scheme for Routing Beraldi and Baldoni (2003) [11] focused on reactive protocols in MANET for routing. Many caching mechanisms use timeout with cache entries to be efficient. However, its efficiency depends on the best timeout strategy. These researchers proposed a proactive routing scheme that does not need timer-based mechanism. The scheme works in such a way that only stale routes are removed from cache while valid routes are never removed. They also embed this scheme into a protocol named Zone Routing Protocol (ZRP). This resulted in application level performance besides increasing protocol efficiency. Ashokraj et al. (2008) [22] studied on broken links and their effects on route cache optimization. They proposed new approach that could reduce router cache problems. Their mechanism was named as Smart Packet based Dynamic Source Routing (DSR-SP). In this approach each node is able to maintain and update the route cache for efficient routing. UZOAMAKA and AJIRIOGHENE (2009) [23] studied DSR protocol in MANETs in terms of cache size and its expiry time. From the research the insights include that smaller cache size affects performance negatively while the cache expiry time has no performance issue on DSR protocol. Husieen et al. (2011) [27] studied DSR protocol with route cache. The caching mechanism avoids unnecessary route discovery process and cause performance improvement in MANET. Kumar and Singh (2012) [30] studied route cache strategy on routing protocols used in MANET. The research revealed that AODV and DSR protocols can provide improved performance with efficient caching strategies. Gouda et al. [31] proposed Gauss-Markov Mobility Model for optimal route stability in MANET. Their protocol was named as Optimal Route Stability Routing Protocol (ORSRP). The results revealed that ORSRP has comparable performance improvement over other routing protocols.

B.Client Cache for Consistency and Cache Sharing Interface Dhivya and Kavitha (2003) [12] studied client cache for MANET performance. The client cache is the temporary memory that helps in the presence of network disconnection. This will help in error-free communication once the node gets back to the network. Chao et al. (2005) [13] proposed a cache sharing interface for mobile nodes for efficient data access. They employed Dynamic Backup Routes Routing Protocol (DBR^2P) for the experiments. They integrated cache sharing interface with the routing protocol in order to leverage caching mechanism in MANET communications. It improves the rate of data reusability.

C. Impact of Cache Timeout and Backup Routes Guo and Yang (2005) [14] studied the impact of backup routes and the cache timeout on reliable source routing. The research revealed that in case of high mobility environment, timeout mechanism has its impact on performance while the backup routes have its impact on the robustness to mobility.

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D. Caching Alternatives and DB Caching in MANETs: Marias et al. (2005) [15] proposed alternative caching strategies for OCSP schemes that are used in MANET. The existing security solutions that make use of public key cryptography and certificates proved to be costly. To overcome this problem a lightweight, on-demand scheme was proposed which is distributed in nature. They discuss time parameters and caching issues for various scenarios. Artail et al. (2005) [16] presented a mechanism that helps in DB caching in MANETs. It is achieved by caching queries and responses. In order to improve the ability of mobile nodes to have access to database, they proposed architecture for DB cache. As shown in Figure 5, there are three kinds of nodes involved such as cache nodes (CNs), query directories (QD), and Backups for Query Directories (BQDs).

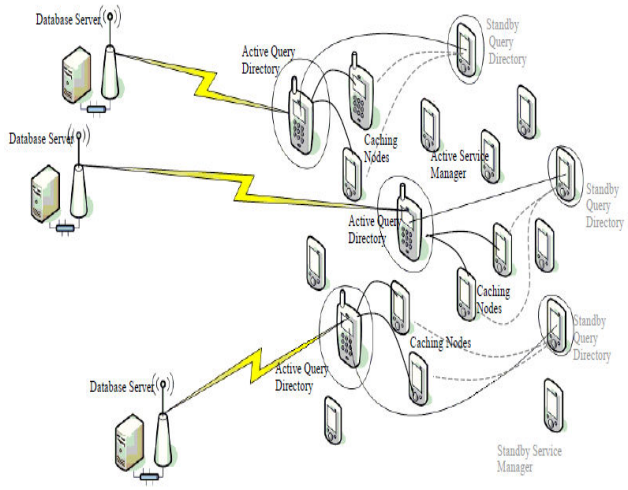

Figure 4 – Architectural overview of DB cache [16]

As the caching data on caching nodes has storage limitations, the data is stored in databases so that the data is made accessible. The DB access is handled using SQL. To make the whole process successful, there are many components that work together. They include service managers and their backup, query directories and their backups, cache nodes that store query responses. Similar kind of solution is found in [32].

E. Transparent Cache-Based Mechanism for MANET: Wang et al. (2005) [17] proposed a transparent cache-based technique for handling the intrinsic characteristics of MANET. It caches data and data paths that are repeatedly used in order to reduce the communication overhead. The mechanism reduces the consumption of bandwidth besides making it an energy efficient approach. The cache – based mechanism is integrated with cache sharing interface [13] and DBR^{2}P.

F. Reclaim-Based Caching Policy with DSR and Other Caching Strategies: Yang and Chu (2006) [18] proposed RBC that enhances the reuse of data form cache. It can address the problem of broken links and broadcasting. It regulates cache capacity from time to time so as to make it more efficient. It achieves better routing performance. Kawish et al. [19] studied routing delay and bandwidth utilization in MANETs with respect to understanding the need for caching. Kawish et al. (2006) [20] proposed dynamic caching in fixed AODV based MANETs. This resulted in reduction of overhead. Cao et al. (2007) [21] proposed a novel protocol for cooperative caching. Gramaglia (2009) [24] studied caching in VANETs for improving IPv6 address configuration. The experimental

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results revealed that caching mechanism reduced configuration times while reducing overhead when caching is used sensibly. Islam and Shaik (2010) [25] focused on cache replacement and data item correlations in MANET. FP-Growth data mining algorithm is used to produce correlations in order to make cache replacement decisions. Thus the cache hit ratio is improved further so as to optimize MANET data dissemination performance.

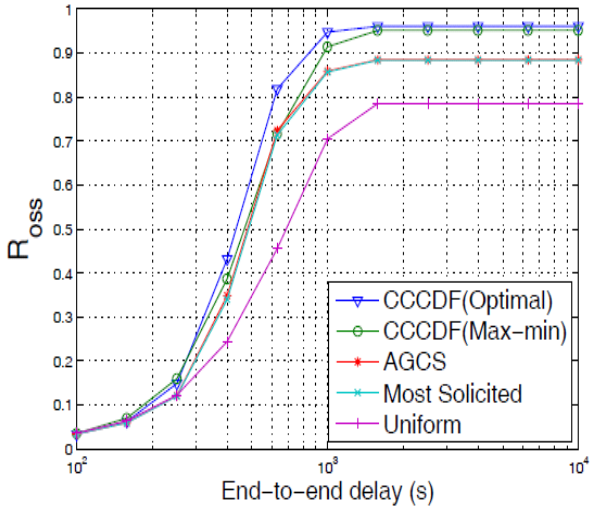

Figure 5 – Performance comparison of various content delivery frameworks [7]

Shanmugavadivu and Madheswaran (2010) [26] focused on data retrieval performance in MANET. They proposed a neighbor group data caching scheme for efficient data retrieval. Their approach has increased cache hit ratio up to 40% besides reducing average latency. Conti and Kumar (2010) [27] studied opportunistic computing that leverages resource sharing, information exchange, executing tasks and so on. It throws light into intermittent connectivity, delay tolerance, and heterogeneity. Joy and Jocob (2012) [29] studied cache replacement strategies in MANET. As cache can improve performance, its replacement periodically also has its impact on the performance. There are many function based cache replacement policies namely target based, SAIU, LUV SACCS, and on bound selection. In the same fashion, the location based strategies include Manhattan, FAR, PA, PAID, and MARS. P2P Cache and Forward mechanisms were explored by Casetti [33] that satisfy optimal information replicas, equal opportunities and responsibilities to all nodes in information dissemination. Their experiments revealed that the solution is feasible and cause less protocol overhead.

G. Cache Replacement in Ad Hoc Networks: Islam and Shaikh [25] proposed a data mining based cache replacement technique for ad hoc networks. Association rule mining using FP-Growth algorithm is used to achieve this. The mining of correlations among data items is done for extracting useful knowledge or heuristics that help in making cache replacement techniques. Their technique improved cache hit ratio when compared to LRU. However, the FP-Tree consumes more memory and computationally expensive that needs further investigation into this area.

V. COMPARATIVE OBSERVATIONS OF CACHING MECHANISMS

This section provides the comparative observations of caching mechanisms. Table 1 reflectsthe important research advances in the

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area of caching and cache invalidation mechanism in MANET.

TABLE 1

Identified Algorithms & Protocols	**Advantages**	**Disadvantages**	**Observations**
.GPS – based connectivity estimation (GPS CE) .Several push & pull based cache invalidation strategies	High throughput, low query latency, and low communication overhead.	It doesn't handle inaccurate location information measured by GPS device.	This research is on MANET connected to Internet.
Extended adaptive TTL (Ex-TTL) algorithm	nformation access efficiency, improved access latency and bandwidth usage, avoids stale data usage.	Fixed TTL and Adaptive TTL do not have clear TTL calculation mechanism and hence it does not support valid data accessing 100%	Overall network performance improved and cache nodes overhead is reduced
EATTL	Supports the failure data reliability design, improves network performance and reduces the cache nodes overhead.	-	One of the TTL based solutions.
COOP uses cocktail approach which consists of 3 basic schemes such as adaptive flooding profile based resolution & roadside resolution.	Significantly reduces response delay and improves data availability with proper settings of the cooperation zone radius.	Fairness of nodes can't be guaranteed when if COOP is altered maliciously.	27% data availability and 59% response delay are improved when compared with SimpleCache
Novel algorithm named Pcache	Fair dissemination of data besides increasing	-	PCache can be applied various applicati

	throughput		ons like name cache.
CCCDF(cooperative cache based content dissemination framework)	Enhanced delivery performance	-	CCCDF optimal and CCCDF max-min strategies
(APPC) - Adaptive push & pull algorithm and (CBDC) – Cluster based data Consistency.	Increases packet success ratio and reduces the delay and overhead	-	Cluster based caching solution
GWSP (Greedy Walk based Selective Push algorithm)	Saves traffic overhead and reduces the query latency	Does not support other consistency models	Saves 41% traffic overhead and 85% query latency
Routing protocol namely C-ZRP by combining zone based caching mechanism with the ZRP (Zone routing protocol)	Provides error-free communication, cryptographic mechanism	-	Proactive caching scheme and does not delay on timer
RBC (Reclaim Based Caching).	Improved network performance	-	Recoverable caching mechanism.
Simple cache and forward mechanism designed light weight content - transparent distributed algorithms	Communications with low protocol overhead	Does not investigate dynamic adaptation of replicas and information survival.	P2P cache and forward mechanism for different network scenarios

VI. CONCLUSONS AND FUTURE WORK

In this paper, the present state of the art of caching strategies used in MANETs for efficient data dissemination and performance, cache invalidation strategies for optimizing cache performance are explored. The nodes in MANET are infrastructure less and there should be cooperative communication. When source and destination nodes are not in the communication range, an intermediate node can receive the data and forward it towards

destination node. That way it is essentially a multi-hop network where each node acts as transmitter and receiver. When data is cached in this scenario, it is possible to reuse data and avoid unnecessary transmissions. Thus caching plays a vital role in the efficient communications in MANET.It is ascertained that various aspects of caching in MANET and the advantages of caching and cache invalidation mechanisms that optimize data availability in MANET besides improving throughput and decreasing computational overhead. The insights from this paper threw light into various problems and solutions pertaining to data availability in MANET. The research can be extended further on caching in MANET by proposing a new caching mechanism that improves efficiency in data dissemination and network performance. It can be achieved based on the improvements on data mining algorithms used to mine correlations among data items in MANET.

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