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Multimedia Caching Strategy Based on Popularity in Mobile Ad-Hoc Network

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Abstract

In this paper, we propose the caching technique to minimize the streaming for multimedia item and the service latency. As mobile ad-hoc network (MANET) has no fixed communication infrastructure, the route maintenance and the transmission management are important issues. Caching technique is used to improve the performance of data access. In the proposed caching scheme, mobile node stores the multimedia item passing through itself and the popular items delivered by the routing nodes located in 1 hop away from itself. We adopt caching policy based on LRU and the popularity and the block distance of multimedia items. In evaluation, we examined our proposed scheme in the view of the caching probability and the cache hit ratio as the function of the network size and the node density under the random waypoint mobility model. From simulation results, we confirm that the proposed scheme offers better performance substantially.

Keywords: *Mobile ad-hoc network, caching, multimedia, streaming service*

1. Introduction

Wireless network has the fixed communication infrastructure such as base station and access point. A node can be directly connected to these devices and communicate with the other devices or Internet. The node's mobility changes a transmission path frequently. As the fixed infrastructure devices control the node's mobility, nodes do not participate in the routing process that manages the delivery path between sender and receiver.

Mobile ad-hoc network (MANET) is the self-configured network that many mobile nodes communicate with each other by a wireless interface under the communication environment without a specific network infrastructure. Nodes in MANET can freely move whenever and wherever they want to. As there are not infrastructure communication devices compared to wireless network, nodes in MANET can communicate with the other nodes by themselves without any help of public communication devices. Thus the mobile nodes should control the entire process such as the route establishment and maintenance, the data delivery and the security problem.

Multimedia is a large volume of data and is played under time-dependent property. To support seamless streaming service, routing protocol should guarantee the delivery path between sender and receiver always exists during the service period. The transmission range of a mobile node is fixed in MANET. To support the full connection among mobile nodes, a mobile node should mutually connect with at least one mobile node within its

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transmission range [1]. The less the number of mobile nodes is in the MANET, the less the connection probability is and finally the service will be blocked due to the lack of the proper path. The data is sequentially transmitted through mobile nodes on the delivery path in MANET. Thus the heavier traffic causes the severe power consumption and the service suspension.

Caching technique copies the original data from another device for future use [2]. This can be reduced the network traffic as the request can be served by the data stored in a mobile node's own cache, not from the node storing the original item. If the delivery path is broken due to the power failure or an excess of a transmission range, and the request data is stored in its own cache, the request can be ceaselessly served without any delay and interruption. Thus caching technique is one of the best policies to solve the problem above mentioned.

This paper presents multimedia caching strategy to reduce the network traffic and the service latency and interruption. To construct and maintain the delivery path, we adopt short distance vector algorithm based on the table-driven and non-hierarchical topology routing protocol for MANET. Multimedia contents requested by mobile nodes are classified by the popularity based on their request frequency. A node requesting multimedia content stores the entire data received from the node storing it. For future use, all nodes on the delivery path, forwarding nodes, temporarily store the forwarded multimedia contents. To increase cache hit ratio, the adjacent nodes 1 hop away from the forwarding temporarily store the only popular items among by-passing multimedia contents in the same way of the forwarding nodes if their cache memory have enough space. Under the proposed scheme, both the forwarding nodes and the adjacent nodes store the multimedia contents. We assume that the multimedia contents are consisted of blocks. The mobile node sends and stores the multimedia contents by block. As a mobile node need not store the whole contents, this method is useful in the environment to be frequently changed the network topology. A cache replacement policy is based on the least recently used (LRU), the popularity of multimedia contents and the block distance of the contents.

The remainder of the paper is organized as follows: The next section we summarize previous work. Section 3 introduces the proposed caching scheme. In Section 4, we present the simulations and analysis of the results. Finally, we give out conclusion in Section 5.

2. Previous Works

Routing is the process that selects the path to deliver communication data in network. Due to the lack of path maintenance devices such as a router, nodes find the proper path between sender and receiver to deliver data before transmitting the necessary data. The path between sender and receiver is constantly changed due to the node's movement. The up-to-date path is important to support the robust service without delaying and blocking the data. The routing protocols for MANET are split into two schemes: table-driven and on-demand [3-6].

With Table-driven routing protocols, all mobile nodes exchange their own routing information with adjacent nodes periodically or whenever the network topology is changed [7-8]. Thus mobile nodes can maintain the up-to-date routing information. If a mobile node wants to connect to another mobile node to deliver data, the node immediately transmits the request packet to the parent node by searching its own routing table stored the up-to-date routing information without the process to search the proper path toward the destination node. This protocol can offer various paths such as the shortest path and the maximum transmission bandwidth path. But table-driven routing protocols have disadvantage of wasting the network bandwidth as the routing process is executed in even the case of the absence of data transmission.

On-demand routing protocol finds and maintains the path merely in the case of data being actually transmitted. If the stored routing information is not used for the predefined time, the routing information is deleted. Compared to table-driven routing protocol, on-demand routing protocol can reduce the consumption of network bandwidth and mobile node's power [9-10]. As mobile node has not the up-to-date routing information, the transmission is delayed until establishing the entire path between the sender and the receiver.

Cao *et al.* [11] introduce a cooperative caching scheme in which multiple nodes share and coordinate cached data stored among mobile nodes. In CacheData scheme, Mobile nodes on the delivery path cache the data when it finds that the data is frequently accessed except all requests for the data are from the same mobile node. Cache replacement policy is independently executed by each mobile node in CacheData scheme. In CachePath scheme, mobile nodes store the path to the node caching the particular data only when it satisfies the closeness condition that is defined as a function of distance to the data source, route stability, its distance to caching node, and the data update rate. The identical data is stored in only one mobile node in the certain area defined by hop counts. These schemes can reduce network traffic but nodes storing popular items are faced with heavier traffic than the others.

Lim *et al.* [12] propose an aggregate caching mechanism called ZoneCooperative that the same data items are cached at least г hops away from itself, where г is a system parameter. To increase the data accessibility, mobile nodes try to store as many data items as possible to reduce access latency when a set of nodes is isolated from the other nodes. In this scheme, the higher the value of Γ is, the longer the service latency is. Also the load of caching nodes storing the identical data is unbalanced as the mobile nodes stores different size of data.

Cho *et al.* [13] propose the caching scheme called NeighborCaching to enhance the utilization of cache space. When mobile node's own cache is full, not used data is copied to neighbor node 1 hop away from itself that is in idle status. The data can be removed to secure the preservation space. If the removed data is needed again, the node requests the data to a neighbor node to store the data. If a neighbor node is far away from itself, the request will send to the data server and the requested data will be stored at the request node. If cache size is small, the data is frequently replaced and it may cause the consumption of network bandwidth.

3. Aggressive Caching Scheme Based on Popularity

In this section, we propose multimedia contents caching algorithm based on their popularity for mobile ad-hoc network. As there is no fixed communication infrastructure in MANET, all mobile nodes establish and maintain the delivery path by themselves. The requested multimedia data is transmitted along the path selected by routing protocol.

3.1. System Model

In MANET, mobile nodes can freely move to anywhere they want to at any time. These nodes' mobility causes the frequent change of the delivery path. If the number of mobile nodes is not sufficient to cover the network area, the path between sender and receiver may be broken. Multimedia is a large volume of data. The period of transmitting the full multimedia data is longer than that of non-multimedia data. If the delivery path is frequently broken, it may cause the decline of QoS (Quality of Service). Let N be the number of mobile node in MANET and R be the transmission range of mobile node. Let $P(i)$ be the connection probability that one mobile node connects with another mobile node within transmission range R and λ be the network density, respectively. $P(i)$ can be calculated as follows.

$$P(i) = (1 - e^{-\pi R\lambda}) \quad (1)$$

As the delivery path can be frequently changed due to the node's movement, network topology is dynamic and temporary. To construct and maintain the delivery route, we adopt short distance vector algorithm based on the table-driven and non-hierarchical topology routing protocol [6]. The maintenance of the delivery path is executed periodically or in time of need. Each node plays a role of the parent node and the child node depending on the hierarchical location in the network topology. The parent node is the mobile node locating close to the sender on the delivery path and the child node is far from the sender. A mobile node should have only one parent node but may have many child nodes more than one. As this method offer only one path from sender to receiver, alternative paths don't exist. But the burden of routing is less than the case of supporting multiple paths.

To determine mobile node's mobility, we use random waypoint mobility model [14]. Random waypoint model is similar to random walk mobility model. Under random waypoint model, a mobile node waits for some time before changing the moving direction unlike random walk model. This is an appropriate mobility model when mobile node frequently changes its moving direction within a geographically limited area.

We assume that multimedia contents are consisted of blocks, where the size of block is defined as the volume of data transmitted for routing interval.

(a) Network topology at time t (b) Network topology at time t+Δt

Figure 1. Mobile Ad-hoc Network

Figure 1 shows a part of mobile ad-hoc networks. There are 6 mobile nodes MN_i{A, B, C, D, E, F} interconnected with one another. Let MN_A be data server that has contents of n items, C_1, C_2 …, C_n. As shown in Figure 1(a), at time t, mobile node MN_A has child nodes MN_B, MN_C and MN_D. MN_E becomes child node of MN_D and MN_A becomes the parent node of MN_D. MN_F becomes child node of MN_E and MN_E becomes the parent node of MN_F. Assume that MN_E wants to play multimedia item C_i and C_i is stored at only MN_A. MN_E sends the request packet to find a mobile node which has stored C_i. The request packet from MN_E arrives at MN_D and MN_F 1 hop away from MN_E. As MN_F does not stored C_i and has not any child node, it does not forward the received request packet and keeps an idle status. As MN_D does not stored C_i, the request packet is forwarded to find C_i. And then, this request packet arrives at MN_A. After receiving the request packet for C_i, MN_A transmits C_i back to MN_D for the requester MN_E. At this time, even though MN_B and MN_C receive C_i, as they have not any child node to need C_i, they do not forward C_i. MN_D

transmits the received C_i back to MN_E. Finally, MN_E plays multimedia contents by using C_i received from MN_D.

As mentioned above, in mobile ad-hoc networks, the request packet and the requested item are forwarded by hop until they reach their final destination such as the mobile node storing the requested item or the mobile node requesting the item. As the battery power of mobile node is limited, it is an important issue to reduce the amount of the transmitted packet and data. Assume that MN_F wants to play multimedia item C_i at time t+Δt. If MN_E has not stored C_i received at time t after executing above mentioned process, C_i is delivered from MN_A to MN_F along the path {MN_A, MN_D, MN_E, MN_F}. But if MN_E has stored C_i received at time t, C_i is delivered from MN_E to MN_F along the path {MN_E, MN_F}. In this case, the total amount of being delivered multimedia data is reduced to one-third.

Figure 1(b) shows the network topology at time t+Δt. The routing information of MN_F is changed. The link to MN_E is broken and new link to MN_D is established. At time t+Δt, C_i is stored in MN_A and MN_E. The request of MN_F for C_i is processed along the path {MN_A, MN_D, MN_F} or {MN_E, MN_D, MN_F}. If MN_D stored C_i transmitted for MN_E at time t, the request of MN_F for C_i is processed along the path {MN_D, MN_F}. In this case, the total amount of being delivered multimedia data is reduced to one-half.

Assume that MN_B wants to play the item C_i at time t+Δt. Only MN_A has stored C_i at time t. With above mentioned caching scheme, the item C_i has been stored at MN_A, MN_D and MN_E at time t+Δt. The distance between MN_B and the nodes storing the item C_i is 2, 3 and 4, respectively. The item C_i for MN_B is transmitted from MN_A that has the shortest path for C_i. At time t, MN_A sends the item C_i for MN_E. MN_D stores the received item C_i as MN_D plays as a role of a router. As MN_B does not join the delivery tree and play a roll of a router at time t, the mobile node MN_B does not store the item C_i. MN_B locates in the transmission range of MN_A at time t. Therefore MN_B can receive the item C_i transmitted from MN_A at time t. If MN_B stores the item C_i from MN_A at time t, the request of MN_B for C_i can handle by using the stored data in its own cache. Thus, the delivery path for C_i is not {MN_A, MN_B} but {MN_B}. The total amount of being delivered multimedia data is reduced to zero.

Let DS (C_i) and $DC(C_i)$ be the distance calculated by hop count from the requester to the server of multimedia contents C_i and the node storing multimedia contents C_i, respectively. The reduced amount of the transmitting data, $Sr(C_i)$, is

$$Sr(C_i) = \sum_{t=1}^{T} \{DS_t(C_i) - DC_t(C_i)\} \cdot B_t(i) \quad (2)$$

where T is the total playing time of multimedia contents C_i and $B_t(i)$ is the block size of C_i at time t, respectively. Let $P_j(C_i)$ and $P_a(C_i)$ be the probability to join in the delivery path for the item C_i and the probability to adjoin to the delivery tree for the item C_i, respectively. The request frequencies of the multimedia contents depend on the degree of their popularity. The caching probability of the item C_i in a mobile node's own cache, $P_c(C_i)$, is

$$P_c(C_i) = \{ P_j(C_i) + P_a(C_i) \} \cdot Z_p(C_i) \quad (3)$$

where $Z_p(C_i)$ is the popularity of the item C_i calculated by the cut-off Zipf-like distribution [14].

3.2. Caching Policy

Multimedia is a large volume of data. We assume that multimedia contents are consisted of n blocks and the size of a block is determined by the routing interval I. The size of the multimedia item C_i is $n \times I$. The total amount of multimedia items is $\sum_{i=1}^{N} n_i \cdot I_i$, where N is the number of multimedia items in MANET. If the cache size of a mobile node is less than the total amount of multimedia items, certain item should be deleted to make space for new item. For this, we adopt the caching policy based on three factors to select victim item V(LRU, Z_p, D), where LRU is the time information of least recently used, Z_p is the popularity of a multimedia item and D is the block distance value of multimedia item that indicates how far the block is from the start block of the multimedia item C_i, respectively.

The process to select a victim item has three steps. First, a mobile node selects the not used item for the longest time as a victim. To calculate LRU more simply, we use the prefixed timer defined as multiple routing interval. Whenever multimedia item is requested, the request count value is increased. If timer exceeds the time limit, the lowest accessed item is selected as a victim and the request count value is set to zero. Second, if more than two mobile nodes have the same LRU value, the lower popularity item is selected as a victim. The popularity is determined by the total access frequency. The value of the total access frequency increases by one whenever the multimedia contents C_i is requested, and does not be set to zero when timer is exceeded the time limit. Third step is to select a victim block when the popularities among multimedia items are the same. If more than two mobile nodes have the same popularity, the total access frequency, the highest offset block is selected as a victim.

Multimedia has the time-dependent property. For streaming service, each block of a multimedia item is played in sequence. The mobile nodes on the delivery path adopt the caching policy above mentioned. But adjacent mobile nodes selectively store the received multimedia item based on its popularity. According to Zipf's law [14], popular items are requested more frequently than unpopular items. As the needed network bandwidth for transmitting popular items is larger than that of unpopular item, to store popular items has more benefit compared to unpopular items. To save the node's battery power and to reduce the network bandwidth consumption for transmitting items, adjacent mobile nodes store the only popular items.

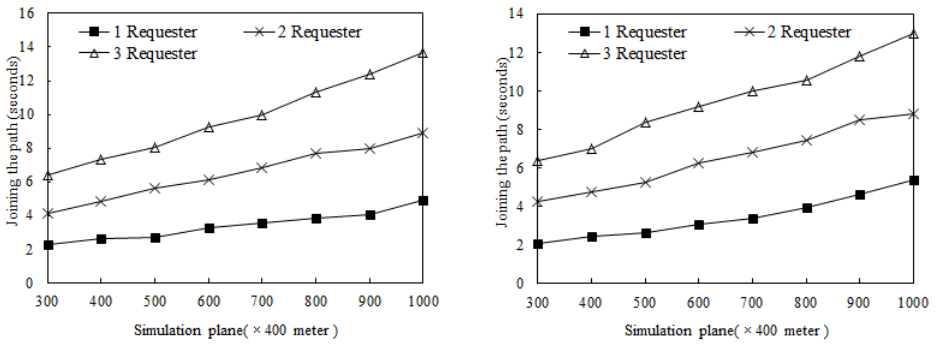
4. Simulation and Analysis

In this section, we show simulation results to demonstrate the benefit of proposed caching scheme in mobile ad-hoc network and analyze the results of performance using it. We assume that all mobile nodes can communicate to any other nodes in the network. To support the fully connection among mobile nodes, we make a simulation model satisfying the condition mentioned in [15]. Initially the mobile nodes are distributed in the network by Poisson distribution. The mobile nodes can freely move to anywhere they want to. For this, we adopt random waypoint mobility model [16]. A mobile node waits for a pause time t_p and selects the new random destination. As random way-point mobility model cannot happen the situations such as an abrupt stop and a sudden change of moving direction, this mobility model is widely used. The parameters of random waypoint mobility mode are velocity and pause time. The mobile node's velocity and the pause time are randomly selected in range [0, maximum speed] and [0, t_p], respectively.

Simulation parameters are listed in Table 1. We also vary some of these parameters to do sensitivity analysis. The size of simulation network is varied from 300m × 400m to 1,000m × 400m in rectangular plan. The multimedia items are consisted of 100 blocks, where the size of each block is 50 KB. The access pattern of mobile nodes is depended on cut-off Zipf-like distribution with skew factor 0.8 [14]. The routing process is executed by 1 second periodically.

Table 1. Simulation Parameters

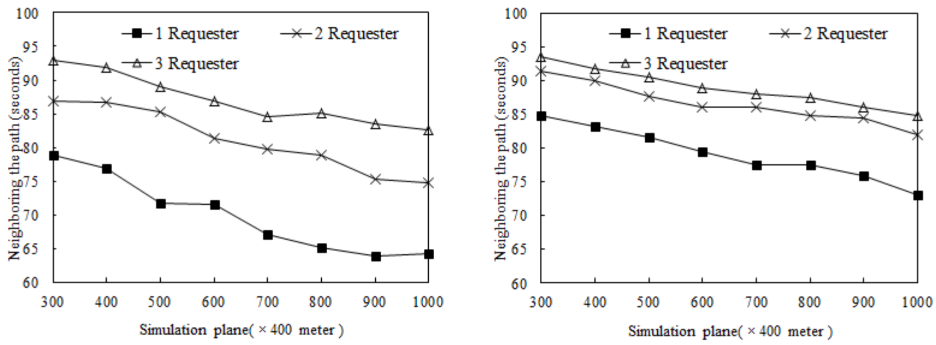
Parameter	Default	Range	Unit
Items	100	-	
Block	100	-	
Block size	50	-	K Bytes
Cache size	5	-	M Bytes
Request rate	1	1 ~ 3	Requests/minute
Bandwidth	10	-	M bits/second
Network area	400 × 400	300 × 400 ~ 1000 × 400	meter
Node density	-	1000 ~ 4500	$meter^2$/node
Velocity(maximum)	10	0 ~ 20	meter/second
Pause time	10	0 ~ 10	second



(a) Maximum velocity 10 m/s (b) Maximum velocity 20 m/s

Figure 2. The Duration of Joining the Delivery Path

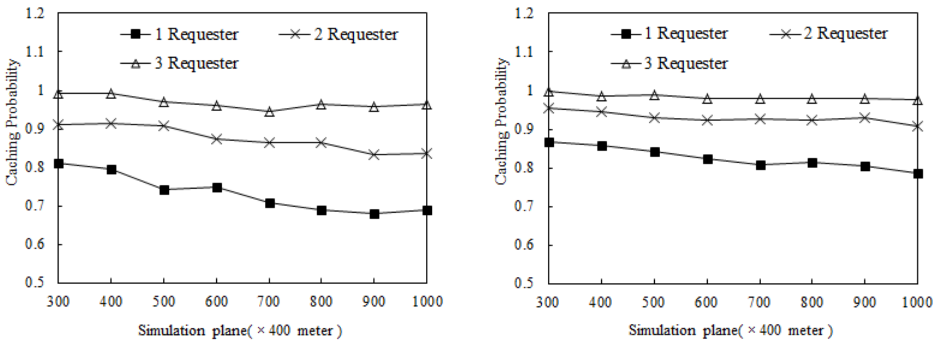
Figure 2 shows the duration of joining delivery path according to the number of the requester range in [1, 3], in the view of the size of simulation plane ranged in [300×400, 1000×400] and the transmission range is 100m. The number of mobile nodes is 100. The mobile node waits for maximum 10 seconds and then moves to the new destination as long as the distance randomly selected in from [0, 300] to [0, 1000]. The X-axis shows the size of simulation plane while the Y-axis shows the duration of joining the delivery path. From the simulation results, the bigger the size of network plane is, the longer the delivery path and the duration of joining delivery tree is. Simulation results about maximum velocity 10 m/s and 20 m/s show that the mobile node’s moving velocity cannot influence the duration of joining the path.



(a) Maximum velocity 10 m/s (b) Maximum velocity 20 m/s

Figure 3. The Duration of Neighboring the Delivery

Figure 3 shows the duration of neighboring delivery path. Simulation environments are the same as those of Figure 2. The X-axis shows the size of simulation plane while the Y-axis shows the duration of neighboring the delivery path. From the simulation result, the more the number of requesters is, the higher the neighboring probability to adjoin the delivery path is. The high velocity causes the network topology to frequently change and increases the probability to pass by the delivery path.

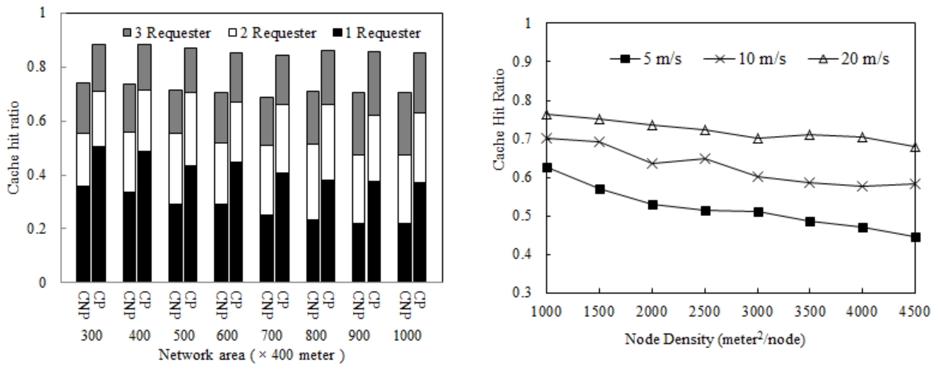


(a) Maximum velocity 10 m/s (b) Maximum velocity 20 m/s

Figure 4. The Caching Probability

Figure 4 shows the caching probability using the proposed caching scheme and simulation environments are the same as those of Figure 2 and Figure 3. The X-axis shows the size of simulation plane while the Y-axis shows the caching probability. From the simulation results, the proposed caching scheme has better performance in high velocity in the view of caching probability.

Figure 5(a) shows the cache hit ratio using the proposed caching scheme in node's maximum velocity is 10 m/s according to the cache schemes such as the cache not used popularity (CNP) and the proposed cache based on the popularity (CP). The deletion probability of all items is the same in CNP using LRU. But in the popularity based caching policy, popular items have lower deletion probability than unpopular items. The rest simulation parameters are the same above-mentioned. The X-axis shows the network size and the Y-axis shows the local cache hit ratio. From the simulation results, the proposed caching scheme has better performance in cases that the node's velocity and the number of requester are high.



(a) Maximum velocity 10 m/s (b) 1 requester

Figure 5. The Cache Hit Ratio

5. Conclusion

In this paper, we proposed the caching scheme for storing multimedia item. A mobile node stores the multimedia item passing through itself and the popular item being delivered by the forwarding nodes linked directly. This increases the probability that the stored multimedia items at its own cache will be used for the future request. Due to the cache capacity limit, the stored data is removed or replaced the new one based on the LRU and the popularity and block offset of multimedia item. The proposed scheme does not try to store the whole blocks on identical item but try to cache a block unit of item. In evaluation, we examined our proposed scheme in the view of the caching probability and local cache hit ratio in the view of the network size and the node's velocity based on random waypoint mobility model. The simulation results show that the caching probability and the cache hit ratio increases in the proportion of the node's velocity and the node density. The popularity based caching policy can achieve high cache hit ratio. The proposed caching scheme has better performance in the cases that the mobile speed and the number of requester is high.

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References

[1] P. Panchapakesan and D. Manjunath, "On the Transmission Range in Dense Ad Hoc Radio Networks," in International Conference on Signal Processing and Communication (SPCOM), (**2001**) January.
[2] X. Sun and Z. Wang, "An effective Caching on Forwarding Table Scheme for Metro Ethernet", International Journal of Advanced Science & Technology, vol. 23, **(2010)** October**,** pp.21-32.
[3] M. S. Corson and J. P. Macker, G. H. Cirincione, "Internet-based mobile ad hoc networking", IEEE Internet Computing, vol. 3, no. 4, **(1999)** July, pp. 63-70.
[4] E. M. Royer and Chai-Keong Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks", IEEE Personal Communications, vol. 6, no. 2, **(1999)** April**,** pp. 46-55.
[5] D. Gupta and A. K. Sharma, "Comparative Investigations on Performance of Routing Protocols in Presence of Realistic Radio Models for WSNs", International Journal of Advanced Science & Technology, vol. 29, **(2011),** pp. 101-111.

[6] C. E. Perkins and P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers", ACM SIGCOMM Computer Communication Review, vol. 24, no. 4, **(1994)** October**,** pp. 234-244.
[7] J. Abdullah, "Performance of QOSRGA Routing Protocol for MANET with Random Waypoint Mobility Model", International Journal of Advanced Science and Technology, vol. 40, **(2012),** pp. 19-34.
[8] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum and L. Viennot, "Optimized Link State Routing Protocol for Ad Hoc Networks", IETF RFC 3626 **(2003).**
[9] D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Networks", Mobile Computing, Kluwer Academic Publishers, vol. 353, **(1996),** pp. 153-181.
[10] C. E. Perkins and E. M. Royer, "Ad Hoc On-Demand Distance Vector Routing", in Proceedings of IEEE Workshop on Mobile Computing Systems and Applications, **(1999)** February**,** pp. 90-100.
[11] G. Cao, L. Yin and C. R. Das, "Cooperative cache-based data access in ad hoc networks", IEEE Computer, vol. 37, no. 2, **(2004),** pp. 32-39.
[12] S. Lim, W. C. Lee, G. Cao and C. R. Das, "Performance comparison of cache invalidation strategies for internet-based mobile ad hoc networks", IEEE international conference on Mobile Ad hoc and Sensor Systems (MASS), **(2004),** pp. 104-113.
[13] J. Cho, S. Oh, J. Kim, H. H. Lee and J. Lee, "Neighbor caching in multi-hop wireless ad hoc networks", IEEE Communications Letters, vol. 7, no. 11, **(2003),** pp. 525-527.
[14] L. Breslau, C. Pei, F. Li, G. Phillips and S. Shenker, "Web Caching and Zipf-like Distributions: Evidence and Implications", INFOCOM '99. Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 1, New York **(1999),** pp. 126-134.
[15] P. Gupta and P. R. Kumar, "Critical Power for Asymptotic Connectivity in Wireless Networks", A Volume in Honor of W.H. Fleming in Stochastic Analysis, Control, Optimization and Applications, **(1998).**
[16] T. Camp, J. Boleng and V. Davies, "A Survey of Mobility Models for Ad Hoc Network Research", Wireless Communications and Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking-Research, Trends and Applications, vol. 2,no. 5, **(2002),** pp. 483-502.

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