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An Optimum Replication Strategy for Multi-Hop Wireless Mesh Network with P2P Data Sharing Settings

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Abstract*— Communication cost is a crucial concern in a 2-dimensional multi-hop mesh network (WMN) where storage spaces are uniformly distributed with P2P data sharing setting. To reduce communication cost, we aim to propose an optimal replication strategy at the participating nodes with P2P content caching scheme. We consider the send/receive rate based on read and write availability of a requested object (content or service) along with the access cost of that specific content/service. We studied other common replication strategies used in WMN environment and made a comparative analysis of those strategies with our proposed one. The outcome of that analysis depicts the effectiveness of our proposed strategy over others.

***Keywords*— Content Caching and Replication, P2P data sharing, Wireless Mesh Network (WMN).**

I. INTRODUCTION

Wireless Mesh Networks (WMNs) consist of multiple wireless stationary access points called nodes and the nodes have network interfaces with limited transmission ranges. Physically neighboring nodes within a threshold distance can communicate with each other and also exchange data and information. In the network there are a number of objects (contents/services) and each object is replicated to facilitate the access of frequent request of clients. To satisfy a request, a replica of the requested object must be discovered and accessed. We focused on P2P data sharing setting which satisfy the particular characteristic of WMNs. Because of the contention for the wireless media between neighboring mesh routers and the traffic on adjacent wireless links, the downloading rate at nodes is significantly reduced when data traverses a long path in a WMN [1]. In our work, we focused on the communication cost. We consider for accessing a single replica, it is also possible to consider the case of accessing multiple replicas [2]. To discover a replica for a requesting node, queries are sent to neighboring nodes, and if necessary, forwarded to further neighbors. After discovering a replicated node, retrieval area is determined by assuming the requesting node as the center of the retrieval area and the distance between requesting node and replicated node as the radius. The idea is to assure that at least one replicated node is available in the retrieval area. Hence, presence of multiple replicated nodes can also be spotted in the same retrieval area. In that case, the nearest one is accessed, Fig.1.

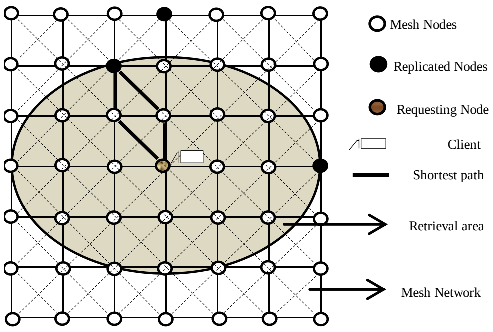

Fig. 1. Replication in WMN

Based on this scenario, in section 2 of this paper we state our further assumptions and simplified definitions. Section 3 exhibits related works on different replication strategies in similar WMN environment. We demonstrated our proposed replication strategy in section 4 and made a comparative analysis between our strategy and few others well studied strategies to evaluate the performance of our proposed replication strategy and presented it in section 5. Finally we concluded in section 6 by mentioning future work in similar environment.

II. ASSUMPTIONS AND DEFINITIONS

We explicitly or implicitly made several simplifying assumptions. First, we assume an unbounded large 2-dimensional mesh network which allows us to ignore details raised from the boundary. Second, we assumed the available storage capacity for each node is uniformly distributed in the network. Third, we assume the requests generate on-demand in the mesh network uniformly and independently and the object size is non-uniform. Fourth, we do not consider the consistency problem arisen from replication since our objective is to study replication strategies only. Finally, we outlined our simplified definitions of few factors related to our replication strategy.

Access Cost: the Euclidean distance between the requesting node and the replica

Sending/receiving rates: read and write availability of the replicated object at a constant time.

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Communication cost: access cost along with the sending/receiving rates for the participating nodes.

To maximize the utilization of available storage of replicated nodes and simultaneously to minimize the communication cost, we determine the density, d_i of the replicas for each P2P *i-th* object according to their popularity, p_i.

III. Related Work

Multi-hop wireless mesh networks have critical characteristics than the Internet. They have low Magnitude and large diameters. Content and service replication can greatly improve their scalability. Many replication strategies have been studied with demand driven and content caching scheme to find an optimum replication strategies. In [2] Shudong Jin and Limin Wang for the first time studies the optimality of replication strategies and explores it in multi-hop wireless mesh networks. They reveal the structure of the optimal replication strategy called *minimum access strategy* to minimize object access cost. They showed that the number of replicas is proportional to p0.667, where p is the access popularity of the object. Their result indicates the inefficiency of demand-driven content and service replication in 2-D mesh networks, where an object is replicated such that the number of its replicas is proportional to *p*. In [3] proposed the Square-root content replication strategy which replicates the *i-th* file in the network such that density is proportional to Square-root of popularity. Amr Alasaad, Sathish Gopalakrishnan and Victor C.M. Leung in **[**1**]** revealed an optimum replication strategies for the P2P objects at the participating mesh routers to reduce the communication cost between peers within the WMN. They determine the optimum number of replicas for each object such that the average access cost of all objects in the network is minimized and propose a distributed (online) algorithm for object replication and showed that the online algorithm mimics the optimal strategy very well. The most relevant work with us is[1] and [2] and the only deference with us is that we consider the content cashing scheme for P2P data sharing settings with upload and download rates for each nodes in WMN.

IV. PROPOSED REPLICATION STRATEGY

We assume that the number of participating caching nodes and their locations are selected by the *Replica Management System (RMS)*. To simplify the analysis, we consider that when a request places each object for the request is fragmented into a number of segments. Let *s* refers the segment and *n* be the total number of segment of the object *i* . A requesting node which requests object *i*, downloads segments of *i* from multiple nodes participating in the retrieval area of the WMN. Hence, we define the cost of accessing object *i* in a two-dimensional WMN as:

$$c_i = \sum_{s=1}^{n} c_i^s$$
(1)

Where c_i^s is the average Euclidean distance between the downloading node and the provider of segment *s*. Since replicated node and participating mesh nodes have different upload/download rates, the average cost of accessing object *i* can be determined as:

$$c_i = \varepsilon_i E_i + (1 - \varepsilon_i) E_i$$
(2)

where E_i is the Euclidean distance between replicated node and requesting mesh nodes which caches a replica of object *i*, and

$$\varepsilon_i = \frac{\mu_m}{\mu_m + \mu_p(\eta \bar{A})}$$
(3)

where εi is the ratio of segments found from the nearest participating replica to segments retrieved from nodes in the retrieval area of the downloading node. $\bar{A}$ is the average number of nodes in the retrieval area. η is the probability of having a segment of object *i* stored at the replicated node. μ_p is the average data download rate at participating nodes in the retrieval area; while μ_m is the average data upload rate at replicated node[1]. Since In a 2-D mesh network, the access cost, defined as the Euclidean distance between the nearest replica and the requesting destination, satisfies the following proportional relationship [2].

$$c_i \propto \frac{1}{\sqrt{d_i}}$$
(4)

We consider (4) as follows

$$c_i = \frac{\Omega}{\sqrt{d_i}}$$
(5)

where Ω is the proportional constant and by ignoring this constant factor from (5) we get

$$c_i \approx \frac{1}{\sqrt{d_i}}$$
(6)

If any object is frequently requested then it should have higher density that means more popularity, *p*. So, that replica can be accessed with a lower cost. The average of total access cost for all P2P objects can be computed by

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$$c = \sum_{i=1}^{n} p_i c_i$$
(7)

where p_i is the popularity of the requested *i-th* object and c_i is the average cost for *i-th* object[2]. When a request for an object takes place, the object is fragmented in to a number of segments. Different segments are fetched from various participating nodes and transmitted through several paths to the requesting node. Finally, these segments are merged in the requesting node to reconstruct that requested object. We compute the average access cost, c_i, of accessing object *i* as a function of d_i by using equation (1) and (2) as:

$$c_i \approx \varepsilon' \frac{E_i}{\sqrt{d_i}} + (1-\varepsilon_i')\frac{E_i}{2\sqrt{d_i}}$$
(8)

where $\varepsilon_i' = \frac{\mu_m}{\mu_m + \mu_p(\eta \frac{\bar{A}}{4d_i})}$ and $0 < \varepsilon_i' < 1$[1]. In our proposed system we assuming unbounded WMN, so this approximation is acceptable for large–scale WMN, where $\frac{E_i}{\sqrt{d_i}}$ accounts for the cost of accessing segments of *i* from the nearest replica at the mesh nodes, and $\frac{E_i}{2\sqrt{d_i}}$ accounts for the cost of accessing segments of *i* from nodes those are located in the retrieval area of a downloading *node* (Fig. 1). Hence, using (6),(7) and (8) we get the total cost as:

$$c = \sum_{i=1}^{n} \frac{E_i p_i}{2\sqrt{d_i}} [1 + \frac{\mu_m}{\mu_m + \frac{\mu_p(\eta\bar{A})}{4d_i}}]$$
(9)

We use fluid model[4] to compute the average number of nodes, Ā which is participating in the network at any instance of time. If we denote all the constant factors with δ_i we get the equation **:**

$$c \approx \sum_{i=1}^{n} \frac{p_i}{\sqrt{d_i}} \delta_i$$
(10)

This cost problem is similar to the utility maximization problem and the optimum solution can be obtained by applying the law of diminishing marginal utility. Let, utility function $U_i(d_i) = -p_i / \sqrt{d_i}$ then the marginal utility function, $U_i'(d_i) = \left(\frac{p_i}{2}\right) d_i^{-3/2}$; where U_i' is a monotone decreasing function of d_i . The law of diminishing returns (also law of diminishing marginal returns or law of increasing relative cost) states that in all productive processes, adding more of one factor of production, while holding all others constant, will at some point yield lower per-unit returns. So, U_i' is a diminishing return of increasing the density d_i for the *i-th* object. To simplify we can write using equi-merginal utility, $U_i'(d_i) = U_j'(d_j)$; where $1 \le i,j \le n$ .This result in $\frac{d_i}{d_j} = (\frac{p_i}{p_j})^{2/3}$ [2]. Thus, we can write the solution for the density of object *i*, $d_i \propto (p_i)^{\frac{2}{3}}$ or,

$$d_i \approx (\delta_i p_i)^{\frac{2}{3}}$$
(11)

where, δ_i is the constant factor we denoted before. From (6) and (11) we get the average cost (12) and the total cost (13) of *i-th* object.

$$c_i \propto (\delta_i p_i)^{-1/3}$$
(12)

$$c \propto \sum_{i=1}^{n} (\delta_i)^{-1/3} (p_i)^{2/3}$$
(13)

The result is somewhat similar to the minimum access strategy and only defer with factor δ_i .In the minimum access strategy when a request place in the WMN , it can be accessed the replica by using only one node in the network. Whereas we consider an efficient scheme of P2P dissemination and in our assumption when a request for an object place in the network then the downloading node will be able to retrieve it from the segments of multiple providers with heterogeneous uploading bandwidth[1]. In our strategy the downloading node is likely to locate large number of replicas of the popular object *i* at nodes in the retrieval area and can access the segments of object *i* at those nodes at low cost. As our main objective for this paper to find out the optimal replication strategies and reduce the total communication cost, so we study other well studied strategies for optimal replication and compare with our strategy as in *Table I.* The result summarizes that for a popular objects the *proportional strategy* gives the strongest and linear preference . So, the access cost for more popular objects is the lowest, but for the less popular objects it is highest. The *Square-Root-Query strategy* gives preference to more popular objects, but among the three strategies, its preference is the weakest because it use the square root of p_i . As a result, access cost and query cost for more popular and less popular objects are most balanced.

TABLE I. Comparison With Other Strategies

Optimal Replication Strategies	$d_i \propto$	$c_i \propto$	$c \propto$
Proportional Strategy	p_i	$(p_i)^{-1/2}$	$\sum_{i=1}^{n} (p_i)^{1/2}$
Our Strategy	$(p_i)^{2/3}$	$(\delta_i p_i)^{-1/3}$	$\sum_{i=1}^{n} (\delta_i)^{-1/3} (p_i)^{2/3}$
Minimum Access Strategy	$(p_i)^{2/3}$	$(p_i)^{-1/3}$	$\sum_{i=1}^{n} (p_i)^{2/3}$

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Square-Root-Query Strategy	$(p_i)^{1/2}$	$(p_i)^{-1/4}$	$\sum_{i=1}^{n}(p_i)^{3/4}$

Our strategy is very similar to the *Minimum-Access Strategy* only defer with factor $(\delta_i)^{-\frac{1}{2}}$. It has reverse proportional relation with the cost which shows that the total communication will decrease if the upload/download rates and other related factors for each node increase. So, our strategy works better than the *minimum access* and achieve the lowest average access cost. We proposed a network protocol stack model in the next section for the network setup which will help for the further reduction of the *communication cost*.

V. Proposed Network Protocol Stack Model

We consider a stable WMN that consists of radio/multi-channel 802.11 mesh routers. All the nodes have same processing power and equal Storage Capacity (S.C.) to accommodate the object replicas and act as server replicas. Fig. 2 depicts the network protocol stack model. We consider the 2-D squared area mesh network topology(Grid-like topology) and use DSR protocol for routing to find the routes because DSR is the simplest , most efficient, completely self-organized, self-configuring and requires no additional network infrastructure or administration[3]. Moreover, it reacts very quickly to the changes in the network due to varying link conditions in wireless networks. TCP is used at the transport layer since it is broadly distributed for Internet access and 802.11 radio is used for MAC layer. We proposed *Replica Management System(RMS)* with *Triple Quorum Replication (TQR)* protocol along with the underlying *TCP protocol* at transport layer.

RMS +TQR
TCP
IP + DSR
802.11 Radio MAC
802.11 Radio PHY

Fig. 2. Mesh Node Protocol Stack

In Grid computing, Replica Management Service (RMS) is a logical single entry point for the user to the replica management system. It has similar functions as *Replica Control Protocol*. It encapsulates the underlying systems and services and provides an uniform interface to the user. RMS has cater the security, collection of data and information, transaction, consistency of replica, optimization and other core task such as metadata and replica location service. Optimization is very important to make sure that the strategy of replicating is optimized by having a Replica Selection, Replica Initiation and Access History. Triple Quorum Replication (TQR) protocol is structuring the quorum into three group of quorum that intersect each other. The number of nodes in each quorum depends on the domain but if there is no priority or domain was given for the groups, the nodes are group based on $q_r=q^2$(where, q_r *is the number of replication in the quorum,* q) to determine the number of nodes in each quorum. For each quorum, at least one mesh router (MR) determined for replication which will help to select a replica in a retrieval area. The TQR protocol also increases the upload rates(read and write data availability) in the network and maintained even with the growth of network size[6] . In the following two sections we describe the network setup and content caching and replication replacement phases.

VI. Network Setup Phase

In the network Phase, we consider two stages:

A. *Identify the Delegates*:

Frist the replica control protocol will detect the nodes to be replicated we call it *Identify the Delegates* in the network. The TQR protocol will determine the quorum size and the nodes to be replicated using the figure 3 algorithm whereas RMS make sure that the strategy of replicating is optimized by having a Replica Selection, Replica Initiation and Access History[6].

```
Procedure Find_Quorum and Delegate node
  Q = number of quorum
  R = number of replica in each quorum
  S = selected node from diagonal site
  N =  number of nodes
  n = number of row or column
Main
  Read N
  n = √N
  If n = odd then
      Q = 3
      Replica in each quorum is, R = n / Q
      If R ≠ odd number then
          Get the nearest odd number for R
  Select the middle replica, S
  Copy the data file at S
  Else
     n = (Column + 1)* (row + 1)
  Return n
```

Fig. 3. Pseudo code for TQR to *Identify the Delegates*

B. *Discover the Replicas:*

The second stage in the network phase is to discover the node with replicated object when a node request place in the network, we call it *Discover the Replicas*. Suppose, *P* is the downloading node, It will send a request to discover the replicas inside the network using the fig. 4 algorithm. It will select at least two nearest replicated nodes in the searching area. Then it will identify the retrieval area according to the location of the corresponding two delegate nodes using the modified minimax facility location problem algorithm [7].

```
    • Assume each node has a list of adjacent nodes called
      'neighbors'
1.Initialize node with:
      Send query <query>:
      M = new Message()
      M.ID = unique_query_ID()
      M.query = <query>
      M.send_time = now()
      M.hops = 0
      M.sender = Requesting node// here the requesting node P
2.Send M to all neighbors
3.For All nodes Initialize:
  Queries_seen: a list of messages;
  Database: the data;
```

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```
  integer max_hops // the maximum number of hops a query should travel
  integer max_time  // the maximum allowed time for a query
4. Receive a query message S :
       if( Database.has_answer( S.query ) )
       {
         send Database.get_answer( S.query )to M.sender;
        return;
       }
     if( not Queries_seen.find( S.ID ) &&
       S.send_time - now() < max_age &&
       S.hops < max_hops )
       {
         S.hops += 1
        send S to all neighbors, except the one that sent S
        add (S.ID, S.send_time) to Queries_seen
remove all entries from Queries_seen older than max_age
return list of  S.hops  to M.sender}
5. If S.hops >=2 && the nearest two delegates of  M.sender then
  { Create the retrieval area using minimax facility location ;
  Return the retrieval area to M.sender;}
End If
```

Fig. 4. Algorithm to discover replicated node in the network and identify the retrieval area.

We modify the minimax facility location problem algorithm by adding the *step 5*.In this step it will check the for at least two replicated nodes according to the requesting node which is M.sender and then determine the retrieval area.

VII. Content Caching and Replication Replacement Phase

In this section we describe the content caching and replication scheme. Suppose mesh router Y is discovered as the file provider for the downloading node P (Fig. 5).

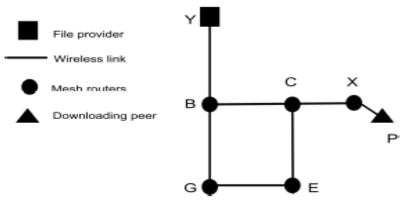

Fig. 5. An example of P2P file sharing setting[8]

The DSR computes the route between Y and P as Y-B-C-X-P. File provider Y then uses the IP layer to broadcast the file's packets required by P after appending the complete route information to P and information about the transmitted file such as file's popularity, number and size of the file segments, segment Id and also the number of optimal replicas required for the file in the network which is determined by the network setup phase. When mesh router B overhears the broadcasted packet, it sniff the information from Y and it rebroadcasts the packet. Next node(MR) on the specified route does the same until the packet reaches the requesting node P(destination)[8].

As we describe in section 4 that, the content caching and replication will be done at the MRs only and to avoid the problem of over replication of the same object in a retrieval area we consider that the object(services & files) will be downloaded to the destination(P) in segments. We also assuming that, when DSR establish the shortest path then the first preferable shortest path will be responsible for the on-demand caching, the MRs which are in the route such as B,C and X will rebroadcast the packet and only the MR that is directly connected to the downloading Node(i.e. node X in Fig .5) will receive an explicit request to cache the object. The first segment of the file will start to download using the route. As DSR will have the other optional route ,the other segments of the file can be downloaded through these routes. So, we consider the optional caching for the MRs which are in the route such as B, G, E and C. If the other routes can start downloading the segments of file at the same time period then it will reduce the communication cost as the route already generated by DSR.

To generalize the algorithm for replacement ,let M be the total number of participating mesh routers in the P2P file sharing for a time period T, B be the maximum number of objects that can be stored at a mesh router's storage disk, A be the average total number of requests for all objects in the WMN within time period T, Si be the number of requests for the i-th object in time period T. Each mesh router computes pi for each file it is responsible for every T time period and sends to RMS. RMS then calculate the ci and c using the table1 and forward the value to all participating nodes(B,C and X) in the route. Each MR then compute the optimal number of MRs that need to cache the object at time t using the following equations where Ri is the optimal number of MR.

$$R_i = \frac{(M*B*c_i)}{c}$$

(14)

If we consider, E_i is the number of MRs that already have the copy of object in their cache in the retrieval area at time *t* [8], then we can calculate the extra number of MRs that we need to cache the object *i* at time *t* to achieve the optimum replication by using: $D_i(t) = R_i(t) - E_i(t)$

(15)

Following is the modified pseudo code for content caching and replication replacement from [6].

- *DSR establish the route with shortest route and all other alternative route info appended to the protocol stack in the RMS (fig 2).*
- *Assume all the node in the route aware of* c_i, D_i *and* R_i *for objet i at the time period t.*
- *The file provider appended the Id-number and size of the file segments*

Procedure at the participating nodes:

1. if $D_i > 0$ then do *on-demand caching*
  if there is free space in mesh router disk && file segment Id is not downloaded **then** Cache the file;
  end if
  if there is no space for incoming file i **then**
    if there are optionally cached files in mesh router disk **then** Evict the file optionally stored at mesh router disk which has least Popularity with higher communication cost and replace it with new incoming file;
    end if
  if all files cached at mesh router are *on-demand* **then** Find a stored file which has least popularity within time T; send file-evict message to the mesh router which is responsible for the evicted file;
  if the file eviction request is approved **then** Evict the file and replace it with new incoming file;

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else find the second least requested file and repeat the process;
end if
end if
end if
if there is no space for incoming file i, all files cached at mesh router are on-demand **then** Contact the mesh router node which cached the file and inform it about the *on-demand* caching and choose the one which has least P_i ;
end if
end if
2. if D_i =0 then do ***optional caching***
if there is free space in mesh router storage disk && file segment is not downloaded **then** cache the file;
else find a file optionally cached with least popularity and higher communication cost && if the incoming file has least communication cost, replace the file by the incoming file;
end if
end if

Fig . 6. Pseudo code for the content caching and replication replacement algorithm.

For *step 1* and *step 2* we consider the segment of file need to be cached in the nodes for the specified route.

VIII. Performance Evaluation

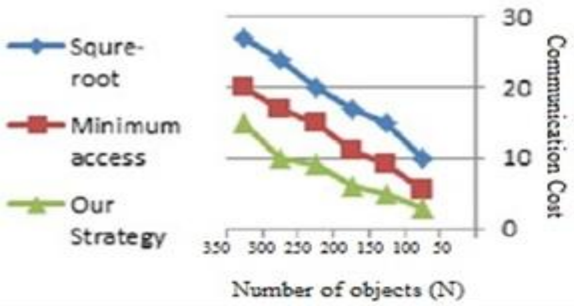

Fig . 7. Performance comparison of replication strategies

We have implemented a simulator using Opnet14.5 and a WMN with 150 stationary nodes (MRs) . Each of the MR was connected at least other four MRs with 100m distance. 802.11b radio with 11Mbs link rate and 250m coverage rate was equipped for PHY and MAC layer. *N* number of distinct and equal size files were distributed at MR in the WMN uniformly. Each file was requested with different number of times and each MR was made to request a file with 10 minutes interval. Each MR can store only 5 files in its cache. We carried out simulations every time for one hour to compute the average file communication cost for varied number of distinct files in the network (*N*). We consider three content replication strategies: 1- Our replication strategy. 2- Minimum access strategy [2], which replicates the *i-th* file in the network such that d_i is proportional to $p^{2/3}$. And 3- Square-root content replication strategy [3] which replicates the *i-th* file in the network such that d_i is proportional to $\sqrt{p_i}$ (Square-root rule). Our result in Fig.7 shows that for all investigated content replication strategies, the average communication cost increased when the number of distinct files in the network increased. This is because when more distinct files are available in a network with limited nodes storage capability, replicas for each file decreases [8]. However, our strategy surpasses other content replication strategies in terms of average communication cost because it optimally replicates files in the WMN, avoids bias against less popular files, adapts to varying files popularity in the WMN, and utilizes the available storage at mesh routers.

IX. Conclusion

In this paper we introduce a replication strategy with content caching in P2P data sharing setting for multi-hop WMNs. Our replication strategy was able to find the optimum number of node to be replicated and also able to reduce the total communication cost from the accessing to the downloading an object to a requesting node compare to other replication strategies. So, this paper achieved its objective. In our future work we will focus on the network model for protocols and route calculation for our replication strategy and re-examine the strategy with other content replication algorithms.

REFERENCES

[1] Amr Alasaad, Sathish Gopalakrishnan and Victor C.M. Leung "Replication Schemes for Peer-to-Peer Content in Wireless Mesh Networks with Network Support", IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications, Toronto, ON, E-ISBN 978-1-4577-1347-7 ,Pages 1135 – 1139,2011.

[2] Shudong Jin and Limin Wang, "Content and Service Replication Strategies in Multihop Wireless Mesh Networks." in Proc. of the ACM MSWiM '05, pp. 79–86, 2005.

[3] Zakwan Al-Arnaout, Qiang Fu, Marcus Frean; "A Novel Distributed Content Replication and Placement Scheme for Wireless Mesh Networks," Australasian Telecommunication Networks and Applications Conference (ATNAC),9-11 Nov, 2011, Melbourne, VIC, Print ISBN:978-1-4577-1711-6.

[4] E. Cohen and S. Shenker, "Replication strategies in unstructured peer-to- peer networks," ACM SIGCOMM Comput. Commun. Rev., vol. 32,no. 4, pp. 177–190, 2002.

[5] D. Qiu and R. Srikant, "Modeling and performance analysis of BitTorrent-like peer-to-peer networks," in Proc. of SIGCOMM '04, 2004.

[6] Rohaya Latip, Tasquia Mizan, Nur Faezah Ghazali, Rabiah Abd Kadir and Feras Ahmad Hanandeh; "Replica Control Protocol : Triple Quorum Replication(TQR) in Data Grid.", The 5th International Conference on Computer Science and Information Technology IEEE Conference(CSIS 2013), March 27-28,2013, Amman, Jordan.

[7] http://www.cs.nyu.edu/artg/internet/Spring2004/lectures/QUERYFloodingAlgorithm.htm.

[8] Amr Alasaad, Sathish Gopalakrishnan and Victor C.M. Leung "Content Caching and Replication Schemes for Peer-to-Peer File Sharing in Wireless Mesh Networks." GLOBECOM Workshops (GC Wkshps), 2010 IEEE, Miami, FL, Print ISBN 978-1-4244-8863-6, Pages 1707 – 1711, 2010.

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