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MESH-DHT APPROACH FOR EFFICIENT RESOURCE SHARING IN P2P BASED WIRELESS MESH NETWORK

P. Prasanna Murali Krishna[1], M. V. Subramanyam[2] and K. Satya Prasad[3]
[1]JNTUK, Kakinada, India
[2], SREC, Nandyal, India
[3]JNTUK, Kakinada, India
E-Mail: pprasannamurali@gmail.com

ABSTRACT

Wireless Mesh Networks (WMN) is a popular communication paradigm due to its low cost and rapid deployment. A large-scale WMN needs a look-up structure to support storage, client mobility and generic services. A Distributed Hash Table (DHTs) spreads construction and maintenance load of abstract index infrastructure over participating nodes, providing simple data access interface. The existing Location aware chord protocol incorporates nodes locality in DHT construction. In addition to node locality, we have proposed MESH-DHT that considers the Link Quality, End to End Delay, Query Response time, Packet Delivery Ratio to improve the QoS parameters in a P2P based Wireless Mesh Network. As WMN's Quality of Service (QoS) parameters are Non-Deterministic Polynomial (NP) hard problem, we have proposed Particle Swarm Optimization (PSO) to improve the QoS parameters of chord when deployed over a multihop environment like Wireless Mesh Networks.

Keywords: Wireless Mesh Networks, Distributed Hash Tables, CHORD protocol, Particle Swarm Optimization, Quality of Service, Non-deterministic Polynomial hard problem.

INTRODUCTION

WMNs are dynamically self-organized/self-configured, with network nodes automatically establishing an adhoc network, maintaining mesh connectivity. WMNs have two types of nodes: mesh routers and mesh clients. Other than routing capability for gateway/bridge functions as in traditional wireless routers, mesh router has additional routing functions supporting mesh networking. Through multi-hop communications, same coverage is possible by a mesh router with lower transmission power [1]. WMNs include a quasi-stationary, mesh routers backbone forming a multi-hop wireless network, where mesh routers relay traffic for others wirelessly. Mesh routers using gateway functionality allow integration of WMN with internet or other wireless networks.

Due to their flexibility, WMNs have a range of application scenarios with the most common being deployment of wireless community networks, where users own mesh routers and form wireless mesh backbone, ensuring access to others for mutual benefit. P2P systems are the next frontier in wireless communication, as wireless users expect to use same services already available on internet, like file-sharing systems like Bit Torrent, voice over P2P applications like Skype and emerging live/on-demand streaming applications like PPLive. Additionally, P2P systems represent an alternative to scale WMN services, like mobility and control management; network routing and anonymity [2].

Peer-to-Peer (P2P) is conventional client-server architecture provided alternative network model. A peer plays roles of client and server simultaneously. The peer initiates requests to other peers, and simultaneously responds to incoming requests from network peers. It differs from traditional client-server model where clients can send requests alone to servers and wait for the latter's

response. P2P systems are characterized as distributed systems where nodes have same capabilities, responsibilities and the communication is symmetric [3]. In P2P systems, nodes have significant or total autonomy from central servers. As a P2P network's system-level dynamics - and hence system level impact of a P2P algorithm - is dependent on local, peer-level parameters, the parameters have to be modeled accurately. Parameters are classified into: content distribution parameters and peer behavior parameters [4].

An overall P2P network characteristic is that nodes send/receive information making them either servers/clients, or 'servants'. P2P file-sharing systems combine sophisticated searching techniques and decentralized file storage permitting users to download files directly from each other. Napster, the first mainstream P2P system, attracted attention for P2P paradigm and millions of users for itself. Napster helped user's trade music, as do most competitors; P2P networks allow users to exchange digital content [5]. Work of serving files in all P2P systems is performed for free by systems' users.

P2P systems are classified as: structured P2P systems and unstructured P2P systems. In the former, connections among network peers are fixed, and maintain information about resources (shared content) that neighbor peers have [6]. So, data queries are directed to neighbor peers with desired data, even if data is rare. Structured P2P systems impose constraints on node (peer) graph and data placement to ensure efficient data discovery. The most common indexing to structure P2P systems is Distributed Hash Tables (DHTs) indexing. DHT, similar to a hash table, provides a lookup service with (key, value) pairs stored in DHT. Figure-1 shows P2P architecture.
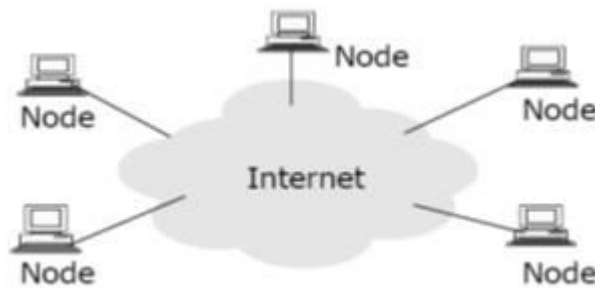
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Figure-1. P2P Architecture.

Participating peers retrieve value associated with a unique key. But, this result in higher overhead compared to unstructured P2P networks. Different DHT-based systems like Chord, Pastry, Tapestry and CAN differ in routing strategies and organization schemes for data objects/keys. Unlike structured P2P systems, unstructured P2P systems form connections among network peers arbitrarily in flat/hierarchical manners. To locate peers with desired content, unstructured P2P systems peers query data based on techniques like random walking, flooding and expanding-ring. In unstructured P2P systems, three designs exist: centralized unstructured P2P systems, hybrid unstructured P2P systems, and decentralized (pure) unstructured P2P systems.

Mobility is the reason for using wireless networks. As entertainment/news updates are part of daily lives, users need access to streaming audio/video applications when moving in areas illuminated by a WMN. All nodes in P2P provide application functionalities. Decentralized P2P architecture increases scalability providing resilience to node failures. Recently, peer-to-peer techniques are used for live media streaming. Practical mobility aspects have a big role in analyzing P2P video streaming applications utility, especially when compared to conventional client-server applications [7].

P2P over WMNs received attention; a combination of both provides new possibilities, but poses challenges also. P2P searching protocol, relying on overlay network, yields penalties regarding bandwidth use, due to partial routing intelligence removal in network layers. DHT enables hash table concept application to a distributed environment [8]. It allows efficient data access through association of a key to every data element. Basically, DHT uses a space of identifiers to guide resource allocation where a resource is either a process for execution or information to be stored. The identifiers space is divided among nodes forming DHT and resources are mapped to that space, using hash function. Every network node is responsible for resources mapped to identifiers who are also called keys.

This study proposes Mesh-DHT as a concept exploiting nodes physical locality to construct an overlay routing geometry using node identifiers reflecting wireless neighbor relations. The proposed location aware Chord is evaluated and compared with Chord for parameters like traffic, success join operation and average query response time. Section 2 describes related works in literature. Section 3 and 4 discuss methodology and experimental results respectively. Section 5 concludes the work.

RELATED WORK

Alasaad *et al.*, [9] proposed WMN-Balance: content lookup algorithm for peer-to-peer file sharing over WMNs. WMN network routing protocols use minimum-hops routing metric to provide QoS for delay-sensitive traffic. WMN-Balance enhances content lookup routing on overlay network, which involves mesh routers that support peer-to-peer file sharing, to offset network unbalanced load.

A content distribution setting in a WMN where, many infrastructure nodes (mesh routers) support P2P content sharing, acting caches/participants was considered by Alasaad *et al.*, [10]. Energy consumption was compared to centralized server scheme using numerical results and detailed simulation. Results revealed great energy consumption reduction (more than an order of magnitude) when an object's few replicas were cached at infrastructure nodes.

Handling P2P traffic in presence of multiple gateways and gateway-centric traffic was studied by Han *et al.*, [11]. Extensive simulations studied the relationships between two traffic types. The need for appropriate routing of P2P traffic was illustrated, motivating creation of Peer-to-Peer Aware Wireless Mesh Protocol (PAWMP), an extension of mesh routing determining the strategy.

Mesh-DHT, an approach to build a scalable DHT in WMNs that placed emphasis on nodes locality and links was presented by Wirtz *et al.*, [12]. A stable, location-aware overlay network was built enabling fully distributed information organization. Proposed DHT geometry by design was closely aligned to WMN's network topology to emphasize local communication. The new approach preserved locality in overlay construction, was robust against node failure, and used local information efficiently. These characteristics ensured that the new approach was scalable in presence of 100's of mesh nodes.

A mobility management protocol named Hierarchical Directory Resolution (HDR) using hierarchical DHT approach was presented by Yang and Bao [13]. Differing from prior DHT solutions based on consistent hashing algorithms, HDR uses a new neighbor-aware contention resolution algorithm to maintain DHT lookup functions. Simulation validated the new protocol's correctness and advantages.

DLSD, a DHT-based localized index structure establishing a locally bounded address spaces hierarchy ranging from few nearby devices to entire network was proposed by Wirtz *et al.*, [14]. Iterating through the hierarchy bottom-up, permits devices to locate most local provider of requested item, thereby reducing multi-hop transmissions and ensuring global reachability. Through

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routing hops reduction, high transmission performance was ensured with reduced interference in network. The new approach's feasibility was evaluated revealing greatly reduced routing overhead and outperforming conventional service discovery and DHT approaches.

Using a P2P paradigm to designing application layer communication and data sharing technologies between MANET participants was proposed by Millar *et al.*, [15]. The architecture allows nodes to send/retrieve data without knowledge of network complexities. So a DHT architecture proposed was optimized for use in such situations proving that the new theorem to be more efficient than current counterpart.

A new solution of a search model that identified frequency of key words automatically and applied inverted index based on DHT to fetch sparse key words was proposed by Gao and Zhan [16]. The model judged whether inverted index or broadcast search based on key words retrieval, when fetching frequent key words. The model improved broadcast algorithm in P2P system adopting a DHT pointer to avoid repetitive messages.

A DHT-based and hierarchical overlay to address issues was proposed by Yu and Vuong [17]. The overlay provided features including topology-awareness, system portability, unicast, responsiveness and DHT integration, and extreme scalability. Successful P2P MMOG technique like interest management could be applied on top of overlay to ensure P2P MMOGs over MANETs.

A possible scenario of reputation techniques application to look up/data retrieval in a P2P network based on Kademlia algorithm was presented by Fedotova and Veltri [18]. The choice was motivated as file sharing is not unique, supported by DHT-based P2P systems. There are other P2P application areas (collaborative/distributed computing) where it considers aspects like risk factor, a "stay on-line" time or many requests without reply.

METHODOLOGY

With increase of P2P network, its applications occupy a majority of network traffic. This is because of P2P network characteristics like various forms of malicious nodes being distributed, anonymous network affected application development, especially in large-scale P2P e-Commerce applications [19]. Due to enormous increase in WMN traffic and due to the limited link capacity, a gateway can become a bottleneck. So load balancing is an important WMN issue. Gateway saturation due to high traffic leads to packet loss, which affects system performance. So traffic load has to be balanced over GWs to alleviate congestion, possible by switching point of attachment of active source serviced congested gateway to those under-used [20].

As distributed P2P applications choose a node that stores data, Chord protocol solves this in a decentralized way offering a powerful primitive: given a key, it determines which node stores key's value efficiently. Peers and resources form a ring in Chord overlay. Within the ring, peers/resources are given an

integer Node ID/Resource ID [21]. Peers store ID in <id, value> pairs, where ID is peer/resource ID, value is peer address information/data storage. Consistent hashing assigns Peer/resource ID, e.g. SHA-1 algorithm. Chord routes message through forwarding messages to successor near destination identifier. Peer first checks finger table records; chooses a successor near destination and forwards a request to it. A peer on receipt of request also does checking and forwards a message to successor. The total cost is not more than log N hops and ½ log N in average where N is overlay peer's number.

In Chord protocol, a node i only managed node M_i, but an arbitrary node *j* may serve many nodes in node management. Chord protocol ensures that [22]: 1) management node of any node i M_i cannot know node *i*; physical address 2) Any node i cannot choose *i* own identity, hence, it just is logical address of a node in Chord network management node *j*. The subtractive clustering algorithm based on distance proximity Chord protocol storage global situation trust value is not contradictory, but needs every node to maintain two simultaneous overlay network protocols.

An efficient load balancing mechanism avoids network congestion and increases network resource use. Optimization is how one finds maximum/minimum value of a function/process. This mechanism is used in physics, chemistry, economics, and engineering where the aim is maximizing efficiency, production or other measures. Optimization is either minimization/ maximization; PSO is used to explore a given problem's search space to find settings/ parameters to maximize/minimize a specific objective [23].

Let $G(t) = (N(t);E(t))$ denote a WMN with node set $N(t)$ and edge set $E(t)$ at time *t*. Users ($U(t)$) and agents ($A(t)$) form the node set where users demand network services, and are mobile and agents dynamically adjust their locations to provide user the network services. Edge set $E(t)$ depends on the users and agents locations, its transmission ranges and time *t*. For a position $\mathbf{p}_i(t) = (x_i(t), y_i(t))$, an edge set can be computed as:

$$E(t) = \left\{ (i,j); i,j \in N(t), i \neq j;\ d_{ij} \leq \min\left(R_i, R_j\right) \right\} \quad (1)$$

where $E(t)$ is edge set at time *t*, R_i transmission range of each node where node $i \in N(t)$, and $d_{ij} = \|\mathbf{p}_i(t) - \mathbf{p}_j(t)\|$ denoting the Euclidean norm of a vector.

The aim is to maximize the connectivity of users by dynamically locating agents in the changing network topology. And efficient load balancing mechanism avoids network congestion and increases network resource use. Optimization is how one finds maximum/minimum value of a function/process. This mechanism is used in physics, chemistry, economics, and engineering where the aim is maximizing efficiency, production or other measures. Optimization is either minimization/ maximization; PSO is used to explore a given problem's search space to find settings/ parameters to maximize a specific objective [23].

If $G(t)$ is the network topology at time t, and $Q(G(t))$ is the percentage of the connected user node pairs. If agent i can move to a maximum of V_i unit distance in a time step, then the maximization of the overall problem can be expressed as:

$$Max\ Q = \frac{1}{T} \sum_{i=1}^{T} Q(G(t)) \qquad (2)$$

$$\|p_i - p_{i-1}\| \leq v_i \ \forall \in A(t), t = 1, \ldots, T \qquad (3)$$

LOCATION AWARE CHORD PROTOCOL

A centralized implementation defeats a network's inherent robustness/capabilities as the central service provider constitutes a bottleneck regarding computation, communication and node failure. A DHT spreads an abstract index infrastructure's construction/maintenance load over participating nodes, while ensuring simple data access interface. For example, WMN mobility support is realized by registering/querying a mobile device's current location from DHT. Besides nodes distribution of functionality/responsibility, both network concepts emphasize redundancy, resiliency, and multi-path routing between nodes. But, constructing/maintaining a stable DHT in a dynamic WMN is challenging.

The location aware chord protocol incorporate nodes locality in DHT construction. Location awareness is employed to map neighboring peers to close by IDs in the unit ring. The idea is to exploit locality, and to assign peers which are close in the physical network with close-by IDs in the unit ring. Nodes that are close in the physical network thus have close identifiers. This close coupling allows minimizing the overhead in DHT communication, because nodes mainly talk to physically close nodes, thus requiring fewer transmissions. Most of the messages are exchanged between a peer and its successor or predecessor in the unit ring. This location awareness is very effective in reducing message overhead. Location awareness is measured using Euclidean distance between the nodes and link quality is measured using Received Signal Strength Index (RSSI). MESH-DHT is proposed that considers the Link Quality, End to End Delay, Query Response time, Packet Delivery Ratio to improve the QoS parameters in a P2P based Wireless Mesh Network. As WMN QoS parameters form a NP hard problem, Particle Swarm Optimization (PSO) technique is used to identify best solution.

PROPOSED PSO OPTIMIZATION

PSO has its ties to artificial life and to bird flocking, fish schooling and swarming theory. PSO also uses swarm intelligence, the property of a system, whereby unsophisticated agents collective behaviors interact locally with the environment create coherent, global functional patterns [24]. PSO algorithm has three steps; generating particles' positions and velocities, velocity update, and the final position update. Here, a particle is a point in design space changing its position from one move (iteration) to another based on velocity

updates. In most PSO implementations, particles move through search space using a combination of attraction to best solution that they have found, and attraction to best solution that a neighborhood particle found.

A set of randomly generated solutions propagates in design space in PSO to an optimal solution over many iterations based on voluminous information about design space assimilated and shared by swarm members. PSO is inspired by bird flocks, fish schools, and animal herds to adapt to their environment, find food sources and avoid predators by implementing an "information sharing" approaches thereby developing an evolutionary advantage [25]. In PSO, the term "particles" are population members who are mass-less and volume-less (or with arbitrarily small mass/volume) and are subject to velocities and accelerations to better behavior.

The following algorithm is used to implement PSO optimization technique:

- Initialize swarm by assigning route set from source to destination.
- Evaluate each particle's fitness function based on like link quality, end to end delay, average query response time and packet delivery ratio.
- For every individual particle, compare particle's fitness value with its P_{best}. If current value is better than p_{best} value, then set this as P_{best} and current particle's position, x_i as p_i.
- Identify particle with best fitness value. Value of its fitness function is identified as g_{best} and its position as p_g.
- Update velocities/positions of all particles with the following equations:

$$v_i^{k+1} = \omega v_i^k + c_1.rn_1.(Pbest_i^k - X_i^k) + c_2.rn_2.(Gbest_i^k - X_i^k) \qquad (4)$$

$$X_i^{k+1} = X_i^k + v_i^{k+1} \qquad (5)$$

- Repeat steps 2–5 till a stopping criterion is met (maximum number of iterations or a sufficiently good fitness value).
- Best route is achieved.

(Parameters for PSO algorithm are c1= 0.12, c2=1.2, w= 0.9, termination criteria: 100 iterations or fitness less than 0.001, Each Query is 512 bytes, rn_1 and rn_2 are random numbers between 0 and 1).

RESULTS AND DISCUSSION

In this study, for experiments number of nodes is considered in the range of 25 to 100 with mobility speed of 20 Kmph. The simulation is conducted for
- Chord
- Location Aware Chord without optimization
- Proposed PSO optimization

The Table-1 to 3 and Figure-2 to 4 explain the results of metrics such as Traffic, Success Join Operation and Average Query Response time.

Table-1. Traffic in network in bytes

Number of nodes	Chord	Location Aware Chord	Proposed PSO optimization
25	9000000	7000000	6731178
50	13899870	11421103	10923736
75	21974480	16714094	15759262
100	32169220	26921172	25491297
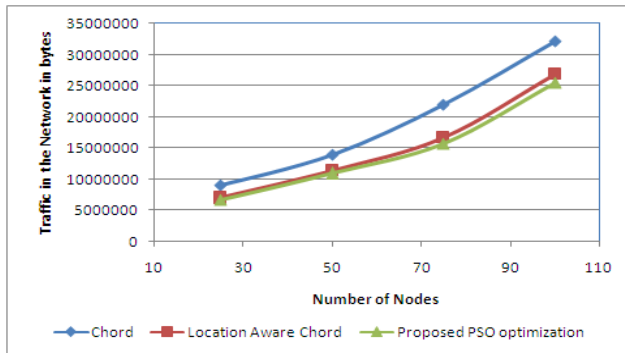
Figure-2. Traffic in network

It is seen from Table-1 and Figure-2 that traffic gets reduced in efficient way for the proposed PSO optimization. That is PSO optimization outperforms when number of nodes used is increases by reducing traffic in the range of 3.92% to 32.94% when compared to Chord and location aware chord techniques.

Table-2. Successful lookup Ratio

| Number of nodes	Chord	Location Aware Chord	Proposed PSO optimization
25	88	91	93
50	83	88	89
75	76	79	80
100	69	73	76
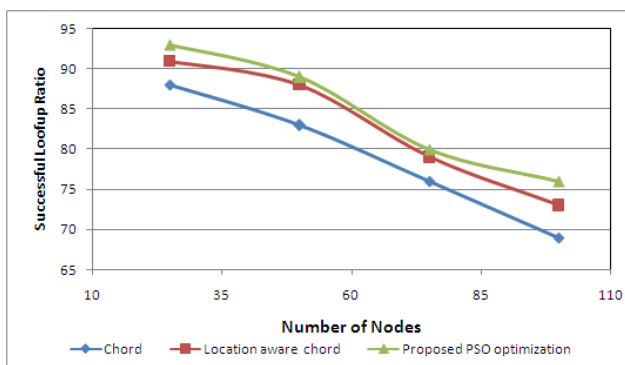
Figure-3. Successful lookup ratio

It is seen from Table-2 and Figure-3 that Success Join Operation gets improved in efficient way for the proposed PSO optimization. That is PSO optimization outperforms when number of nodes used is increases by improving successful lookup ratio with the range of 1.13% to 9.66%

when compared to Chord and location aware chord techniques.

Table-3. Average query response time in Sec

Number of nodes	Chord	Location Aware Chord	Proposed PSO optimization
25	0.2624	0.2142	0.1976
50	0.322	0.2725	0.2567
75	0.395	0.3446	0.3198
100	0.5151	0.4295	0.4056
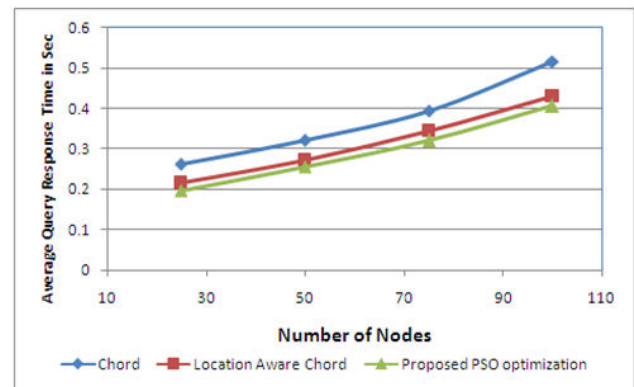
Figure-4. Average Query Response time in Sec

It is seen from Table-3 and Figure-4 that average query response time gets reduced in efficient way for the proposed PSO optimization. That is PSO optimization outperforms when number of nodes used is increases by reducing average query response time to the range of 5.72% to 28.17% when compared to Chord and location aware chord techniques.

CONCLUSION

WMNs are emerging networks suiting mobile computing nodes. WMN has mesh routers and mesh clients, with the former having negligible mobility and form WMN's spine. A structured approach enhances lookup performance in high bandwidth wired network; but unnecessary overhead is generated in overlay networks impacting WMN performance negatively. Proximity neighbor selection effectiveness depends on routing algorithm used by DHT. The location aware chord protocol incorporates nodes locality in DHT construction. In addition to node locality, the proposed MESH-DHT considers the Link Quality, End to End Delay, Query Response time, Packet Delivery Ratio to improve the QoS parameters in a P2P based Wireless Mesh Network. Traffic was reduced efficiently with the proposed PSO optimization. PSO optimization outperforms when number of nodes used increases by reducing traffic within a range of 3.92% to 32.94% compared to Chord and location aware chord. Similarly average query response time is reduced and success lookup ratio improved efficiently for the proposed PSO optimization technique.

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