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(54) **Title**: COOPERATIVE RELAYING DATA METHOD AND SYSTEM FOR WIRELESS MESH NETWORK

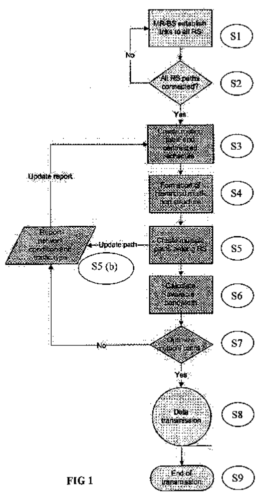

FIG 1

(57) **Abstract**: The present invention discloses a method and system of cooperative data relay in a wireless mesh network. The system comprises at least one multi-hop relay base station (MR- BS) (100) and a plurality of relay station (RS) (200) which are configured to support mesh connections. The method in accordance with the preferred embodiments of the present invention provides capabilities to enable optimal data transmission by way of cooperative relay between the relay stations (RS) (200). Data transmission is initiated upon established the optimized multiple paths with respect to the relay stations (RS) (200). The determination of the optimized multiple paths is based the details of relays stations (RS) (200) provided to the reference table and centralized scheduling at the multi-hop relay station (MR-BS) (100). The reference table and centralized scheduling include, but not limiting to, all details and status pertaining to the plurality of relay stations (RS) (200) within the network, network condition and traffic type.

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COOPERATIVE RELAYING DATA METHOD AND SYSTEM FOR WIRELESS MESH NETWORK

Field of the Invention

The present invention generally relates to wireless communication networks, and more particularly to cooperative relaying data method and system with centralized scheduling capability for use in wireless mesh networks.

Background of the Invention

Wireless mesh networks have been universally employed in various scenarios to deliver a wide range of services for the purpose of, among many others, rural or suburban community networking, private networks, public safety and video surveillance. Essentially, wireless mesh networks are of particular importance for systems involving high data throughput or transmission and extended coverage, for instance bandwidth intensive applications with rich or high quality multimedia content, interactive games and large data transfer.

One of the most recognized characteristics relative to wireless mesh networks at present is the possibility to provide multi-hop communication concept. With multi-hop communication, data are suitably configured to be relayed from source to destination with the assistance of multiple or a plurality of paths, whereby traffic is routed through nodes which may comprise of a plurality of mesh routers and clients. It is known that with the multi-hop communication concept a system performance can be significantly improved, as with such concept, increased data rate is highly feasible, and therefore able to address complications in relation to communications distances. Typically, in multi-hop communication, the transmission between source and destination is routed through one link and in multi-hop fashioned, in which the link is accordingly established by way, for instance, determining the hop count, preferably with the shortest distance, or by way of other suitable routing metrics including expected transmission time, or interference aware routing metric. In order to obtain best possible performance, one of the primary causative aspects is to select and thus situate the most suitable characteristics for the relay stations (RS).

Although multi-hop communication may be expedient for users, the primary concern in relation to such concept of communication at present is the throughput degradation. This is because technically, only one link is optimized to establish communication path between source and destination as mentioned earlier, may eventually lead to path loss. In addition, as a result to the single path being utilized, the distributed mesh nodes are not fully exploited in the network, even though the other mesh nodes might be in idle mode.

Recognizing the setbacks as aforementioned, the present invention has been accordingly developed to alleviate the discussed setbacks in addition to providing further enhancement with respect to the multi-hop communication concept.

The present invention therefore provides a multi-hop communication method and system which emphasizes cooperative communications and scheduling mechanism to resolve the aforementioned setbacks.

It is therefore a primary object of the present invention to provide a cooperative relay method and system for wireless mesh network with scheduling mechanism, thereby allowing each mesh node to be aware of the status of the neighboring nodes, and invoke the communications through multiple paths.

It is still further object of the invention to provide a cooperative relay method and system for wireless mesh network which enables establishing more than one link between source and destination.

It is yet a further object of the present invention to provide a cooperative relay method and system for wireless mesh network that employs joint optimization of scheduling and routing thereby increasing the network utilization and efficiency.

It is yet another object of the present invention to provide a cooperative relay method and system for wireless mesh network with the capability to characterize the bandwidth allocation process for radio resource management (RRM) based on the availability of bandwidths and characterizes the quality of service (QoS) parameters for connections.

These and other objects, features and advantages of the present invention will be apparent from the following detailed description of preferred embodiments thereof.

Brief Description of the Drawings

The invention will be more understood by reference to the description below taken in conjunction with the accompanying drawings herein:

FIG 1 illustrates the schematic flow chart of the method and system in accordance with the preferred embodiments of the present invention;

FIG 2 illustrates an exemplary of a network hierarchal structure for the application of the method and system of the present invention; and

FIG 3 illustrates the binary numbering based on hop count and relay station ID based on a preferred embodiment of the present invention.

Summary of Invention

In one embodiment, the present invention provides a method for providing cooperative relay of data within a wireless mesh network, comprising the steps of:

i) establishing links to a plurality of relay stations (RS) within said network;

ii) creating reference table and centralized schedule upon established the links with relay stations as in step i);

iii) forming hierarchal multi-hop structure based on said network;

iv) creating multiple paths among said relay stations (RS) from step i);

v) updating reference table and centralized schedule of step ii) based on network condition and information related thereto;

vi) calculating available bandwidth within the network;

vii) determining the optimal paths from step iv); and

viii) initiating transmission of data to relay stations (RS)

wherein the step updating reference table and centralized schedule of step v) further comprising the step of generating an update report for said reference table and centralized schedule.

There is further provided a system for cooperative relay of data within a wireless mesh network comprising: at least one data relaying device; a plurality of data receiving and retransmission device; wherein at least one of the data receiving and retransmission device is connected to the data relaying device; characterized in that the data relaying device is configured to create, periodically update and maintain reference table and centralized schedule, said reference table and centralized schedule comprising all details pertaining to the status of the data receiving and retransmission device, including link condition and network traffic status; wherein data transmission is initiated from said data relaying device to the data receiving and retransmission device based on the details of the reference table and centralized schedule.

Detailed Description of the Preferred Embodiments

In line with the above summary, the following description of a number of specific and alternative embodiments is provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details.

It is further noted that the exemplifications which may be provided within the specification are meant to better elucidate the operational effect and embodiments of the present invention and therefore should not be construed as limiting the scope of protection.

The present invention provides centralized scheduling feature for use particularly in a wireless mesh network, said feature is the key difference compared to prior arts, said centralized scheduling is provided at the multi-hop relay station (MR-BS) thereby ensuring all mesh connectivity among the relay stations (RS) are managed efficiently.

The aforementioned capability is materialized with the assistance of the wireless backhaul interconnections among the mesh nodes distributed over a predetermined geographical area in order to provide reliable coverage for accessing client terminals and subscriber stations.

For instance, in the event that there is a set of possible K transmission links;

$$C(n) = c_1(n) + c_2(n) + c_3(n) + \Lambda \ + c_K(n)$$

The objective is to minimize the total transmission time required for all mesh nodes to received their demanded number of bit, r_b

$$\frac{r_b}{\sum_{t=1}^{K} T_t}$$

With concurrent transmission, the probability of single link delay, congestion or failure is therefore minimized. Further, transmission of data could be relayed through more than one path with distributed weight carrying different number of data packets based on channel conditions, available bandwidth and traffic intensity.

The distribution and weight of different independent paths are determined through centralized reference and scheduling mechanism. The achievable throughput for the cooperative relay method is obtained with the below equation:

$$S(n) = \sum_{k=1}^{K} c_k(n)\alpha_k p_k(n)$$

Where $c_k(n)$, α_k and $p_k(n)$ denote transmission data, adaptive weight and transmission path, respectively.

Each of the multi-hop relay base station (MR-BS) (100) of the method and system in accordance with the preferred embodiments of the present invention is configured or designed to perform the tasks within a wireless mesh network, said tasks will be described shortly herein after, with reference to the drawings.

FIG 1 shows a schematic flow diagram of the preferred embodiments of the present invention. In the first step S1 the multi-hope relay base station (MR-BS) (100), being the relaying node is configured to establish links with all available relay stations (RS) (200), as the receiving nodes within the network. It is understood that in order to establish links with all available relay stations (RS) (200), each relay station (RS) (200) is configured to be aware of the hierarchal structure or nature of the communications to the mobile station (MS). The location and proximity of the relay stations (RS) (200) to the multi-hop base station (MR-BS) (100) are important to determine the node ID and the hop count for each of said relay station (RS) (200), as such details aid significantly in recognizing the downlink traffic from the access service network gateway (ASN-GW) to the mobile station (MS) and thereby routing is performed through multiple downlink paths or relay station (RS) nodes. For instance, and as shown in FIG 3, the node ID and the hop count for the closest relay station (RS) may be assigned as 001, while the subsequent hop may be assigned as 010. Noticeably, the numbering convention has to maintain certain consistency such that the hop count between the mobile station (MS) and multi-hop relay base station (MR-BS) (100) can be determined.

Upon established all paths for relay stations (RS) (200) as shown in the second step S2, the creation of reference table for use in routing and centralized schedule is initiated in step S3, which is considered as one of the core steps in accordance with the preferred embodiments of the present invention. For this step S3, status of each relay stations (RS) (200) which may include details pertaining to the number of hop to multi-hop relay station (MR-BS) (100), ID of neighboring codes, number of user served, traffic condition or traffic type, available bandwidths (for uplink and downlink) is suitably updated and maintained within the system. It should be noted that characteristics such as the number of user served, amount of traffic carried and available bandwidth play a significant role in maintaining efficient control of the network for immediate user access usage and for relaying traffic from other modes. In addition, the centralized scheduling of the traffic flow and other relevant details will assist in providing efficient utilization of the available bandwidth and capacity within a network. As a result, load balancing can be obtained whereby a node with high number of users and congested will not be utilized for relaying to other relay stations (RS) (200) which are positioned or located substantially further from the multi-hop relay base station (MR-BS) (100). An exemplary of tabulated information at the multi-hop relay base station (MR-BS) (100) on the status of each relay station (RS) (200) within the network is provided in TABLE 1 below.

TABLE 1

Tabulated information at the multi-hop relay base station (MR-BS)

Node ID	**Number of hop to MR-BS**	**Neighboring nodes**	**Number of user served**	**Traffic condition / traffic type**	**Available BW (UL / DL)**
RS1	1	RS2, RS3	*n1*	*t1, q1*	*BW1*
RS2	1	RS2, RS4	*n2*	*t2, q2*	*BW2*
RS3	2	RS1, RS4, RS5	*n3*	*t3, q3*	*BW3*
RS4	2	RS2, RS3, RS5	*n4*	*t4, q4*	*BW4*
RS5	3	RS3, RS4	*n5*	*t5, q5*	*BW5*

From step S3, hierarchal multi-hop structure formation is performed in step S4. It is noted that the formation of the hierarchal structure may depend on the type of mesh network involved. An exemplary of the application of the system of the present invention is as shown in FIG 2, whereby it is shown that the present invention is configured based on WiMAX mesh network. In this structure, the access service network gateway (ASN-GW) may serve a plurality of multi-hop relay base station (MR-BS) (100). Each of the multi-hope relay base station (MR-BS) (100) comprises of several relay stations (RS) (200) connected in mesh configuration. From the plurality of relay stations (RS) (200) at least one is preferably connected to the multi-hop relay base station (MR-BS) (100) in order to allow connection to gateway for some applications, including the internet. Suitably, subscriber and mobile stations (MS) can be connected to the network through either relay stations (RS) or other base stations (BS). In accordance to another preferred embodiment of the present invention, the multi-hop relay base station (MR-BS) (100) maintains a reference or routing table consisting of status and traffic condition of the plurality of relay stations (RS) (200) which are connected to the multi-hop relay base station (MR-BS) (100).

Next, in step S5, multiple paths among the relay stations (RS) (200) are created prior to calculating and characterizing bandwidths based on the available and the demand bandwidths in step S6. This step may further involve characterizing quality of service (QoS) parameters, said parameters may include, but not limited to, latency, jitter and throughput assurance, in addition to quality of service (QoS) management capability (USG, rtPS, ErtPS, nrtPS, BE) with respect to different connections and service flow. The creation of multiple paths among the relay stations step may further involve the step S5(b) for providing updating reports or status on updated paths, network condition as well as traffic type, whereby these reports are suitably maintained within the network particularly for creating the reference table and centralized schedule of step S3. It is noted that the method of the present invention enables these reports and status to be updated periodically.

In the event that the optimized multiple paths are determined and thus obtained as in step S7, data transmission is initiated as in step S8. Data transmission step S8 may further include synchronization for the downlink traffic and thereby providing load balancing for the plurality of relay stations (RS) (200) within the mesh topology. On the contrary, in the occurrence that the optimized multiple paths for optimal communication are not obtainable, a report pertaining, but not limited to, the network condition and traffic type based on the unobtainable optimized multiple paths is generated and therefore used to update the reference table and centralized schedule of step S5 (b). The overall data transmission process ends at step S9.

Having thus described the preferred embodiments of the present invention, it should be noted by the person skilled in art that there may be modifications within the scope of invention. Therefore, the present invention is not limited to the specific embodiments as illustrated therein, but is limited by the following claims.

CLAIMS

1. A method for providing cooperative relay of data within a wireless mesh network, comprising the steps of:

i) establishing links to a plurality of relay stations (RS) (200) within said network;

ii) creating reference table and centralized schedule upon established the links with relay stations as in step i);

iii) forming hierarchal multi-hop structure based on said network;

iv) creating multiple paths among said relay stations (RS) (200) from step i);

v) updating reference table and centralized schedule of step ii) based on network condition and information related thereto;

vii) calculating available bandwidth within the network;

viii) determining the optimal paths from step iv); and

ix) initiating transmission of data to relay stations (RS) (200)

wherein the step updating reference table and centralized schedule of step v) further comprising the step of generating an update report for said reference table and centralized schedule.

2. The method as claimed in Claim 1 wherein the step of calculating available bandwidth within the network further comprises characterizing bandwidth allocation process for radio resource management (RRM) based on available bandwidths and the demand bandwidths.

3. The method as claimed in Claim 1 wherein the steps of creating and updating the reference table and centralized schedule include the step of characterizing quality of service (QoS) parameters, said parameters including latency, jitter, and throughput assurance.

4. The method as claimed in Claim 1 to 3 wherein the steps of creating and updating the reference table and centralized schedule further include the step of characterizing quality of service (QoS) management for connections.

5. The method as claimed in Claim 1 wherein the step of initiating the transmission of data to relay stations (RS) (200) comprises synchronization for downlink traffic thereby providing load balancing for the plurality of relay stations (RS).

6. The method as claimed in Claim 1 wherein the reference table and centralized schedule include details pertaining to hop count, neighbor ID, load and/or user, traffic condition , traffic type, and these details are updated periodically.

7. The method as claimed in Claim 1 wherein the network is a wireless mesh network.

8. A system for cooperative relay of data within a wireless mesh network comprising:

at least one data relaying device (100);

a plurality of data receiving and retransmission device (200);

wherein at least one of the data receiving and retransmission device (200) is connected to the data relaying device;

characterized in that the data relaying device (100) is configured to create, periodically update and maintain reference table and centralized schedule, said reference table and centralized schedule comprising all details pertaining to the data receiving and retransmission device (200);

wherein data transmission is initiated from said data relaying device (100) to the data receiving and retransmission device based on the details of the reference table and centralized schedule.

9. The system as claimed in Claim 8 wherein the data transmission is initiated upon established the optimal paths based on the details of receiving and retransmission device.

10. The system as claimed in Claim 8 wherein the data relaying device is a multi-hop relay base station (MR-BS) (100).

11. The system as claimed in Claim 8 wherein the data receiving and retransmission device is a relay station (RS) (200).

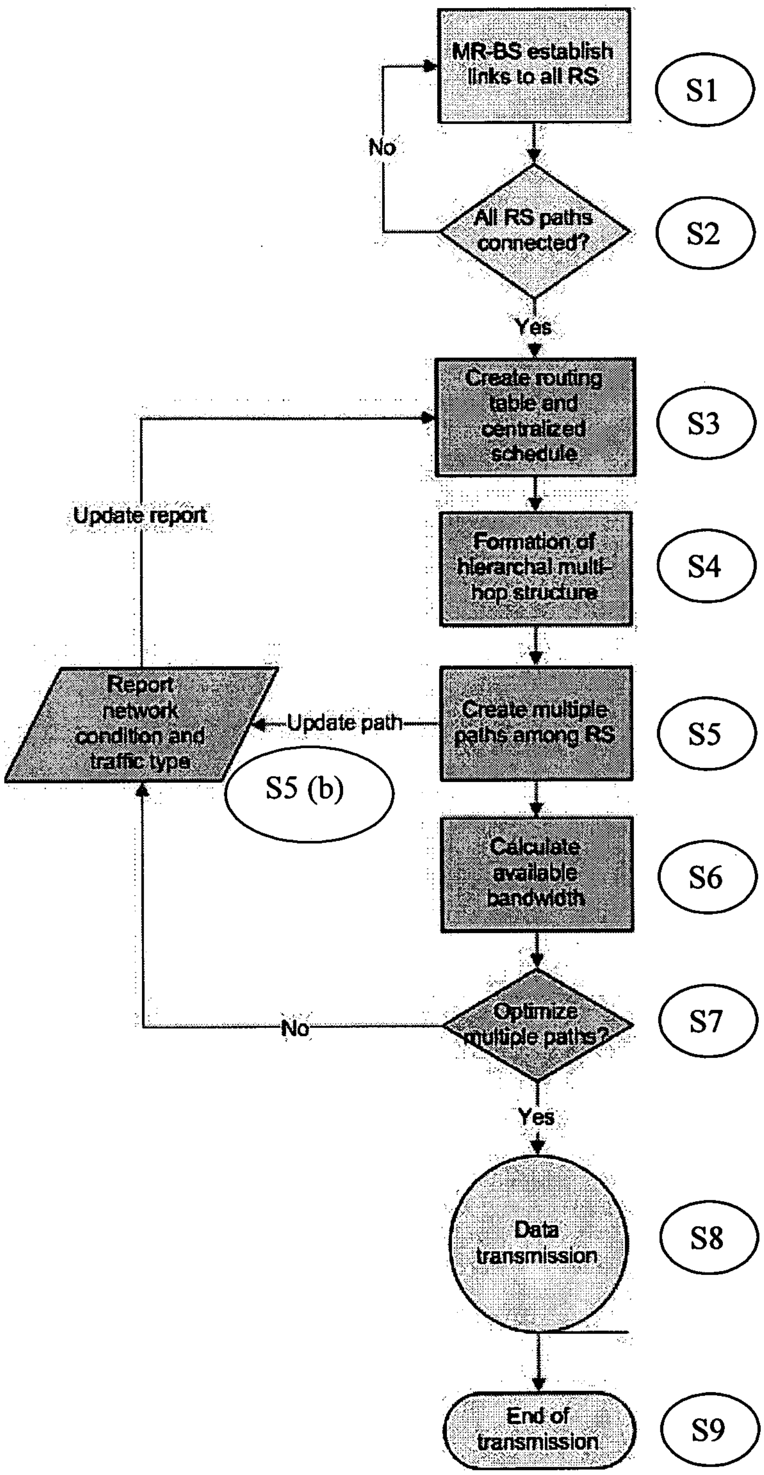
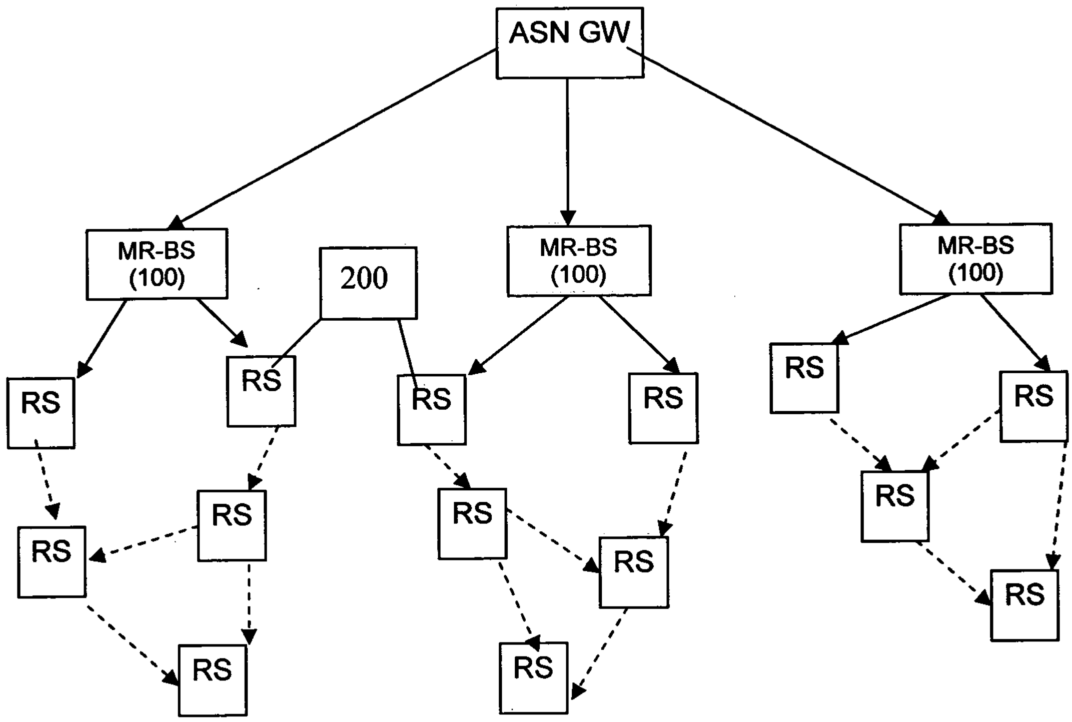

MR-BS establish links to all RS
S1
No
All RS paths connected?
S2
Yes
Create routing table and centralized schedule
S3
Update report
Formation of hierarchal multi-hop structure
S4
Report network condition and traffic type
Update path
Create multiple paths among RS
S5
S5 (b)
Calculate available bandwidth
S6
No
Optimize multiple paths?
S7
Yes
Data transmission
S8
End of transmission
S9

FIG 1


ASN GW
MR-BS (100)
200
MR-BS (100)
MR-BS (100)
RS
RS
RS
RS
RS
RS
RS
RS
RS
RS
RS
RS
RS
RS
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RS

FIG 2

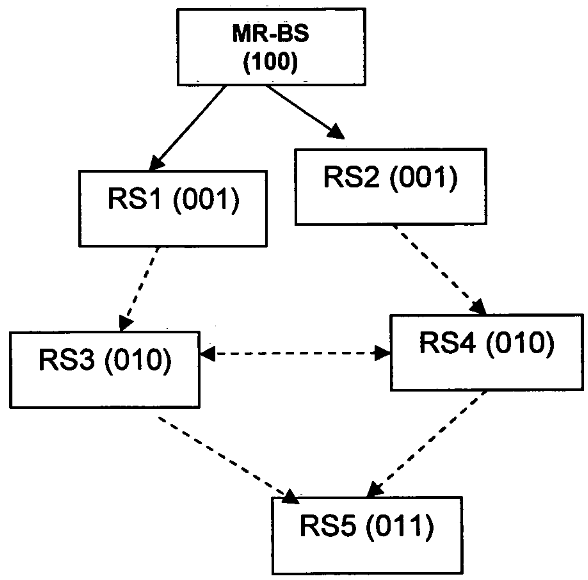

FIG 3