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APPLICATION NUMBER: 62/015,853

FILING DATE: *June 23, 2014*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS US62/015,853



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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Mehmet	KARACA	Istanbul, TR
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Additional inventors are being named on the _____ separately numbered sheets attached hereto.

TITLE OF THE INVENTION (500 characters max):

 SMART UR

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ENCLOSED APPLICATION PARTS (check all that apply)
☒ Application Data Sheet. See 37 CFR 1.76. ☐ CD(s), Number of CDs _____
☒ Drawing(s) Number of Sheets 19 ☐ Other (specify) _____
☒ Specification (e.g., description of the invention) Number of Pages 19

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☒ Applicant asserts small entity status. See 37 CFR 1.27.
☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Applicant must attach form PTO/SB/15A or B or equivalent.
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 2 of 2

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the invention was made by an agency of the U.S. Government. The U.S. Government agency name is: _____

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SIGNATURE /John A. Castellano/ DATE June 23, 2014

TYPED OR PRINTED NAME John A. Castellano REGISTRATION NO. 35,094
(if appropriate)

TELEPHONE 703-668-8000 DOCKET NUMBER 16773-000010-US-PS1

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		
<p>The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.</p>			

Secrecy Order 37 CFR 5.2

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--------------------------	---

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Inventor 1					Remove
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Prefix	Given Name	Middle Name	Family Name	Suffix	
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Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
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Inventor 2					Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Firat		BIRLIK		
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		

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	Eren		SOYAK	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
City	Istanbul	Country of Residence ¹	TR	

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Address 2	Celik Is Merkezi, Mecidiyekoy			
City	Istanbul	State/Province		
Postal Code	34394	Country i	TR	
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Application Information:

Title of the Invention	SMART UR		
Attorney Docket Number	16773-000010-US-PS1	Small Entity Status Claimed ☒	
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Filing By Reference :

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		

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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.



NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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☒ Authorization to Permit Access to the Instant Application by the Participating Offices

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In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

- ☐ Assignee
 ☐ Legal Representative under 35 U.S.C. 117
 ☐ Joint Inventor
- ☐ Person to whom the inventor is obligated to assign.
 ☐ Person who shows sufficient proprietary interest

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

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Address 2			
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Phone Number		Fax Number	
Email Address			

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Assignee 1

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	16773-000010-US-PS1
		Application Number	
Title of Invention	SMART UR		

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First Name	John	Last Name	Castellano	Registration Number
35094				
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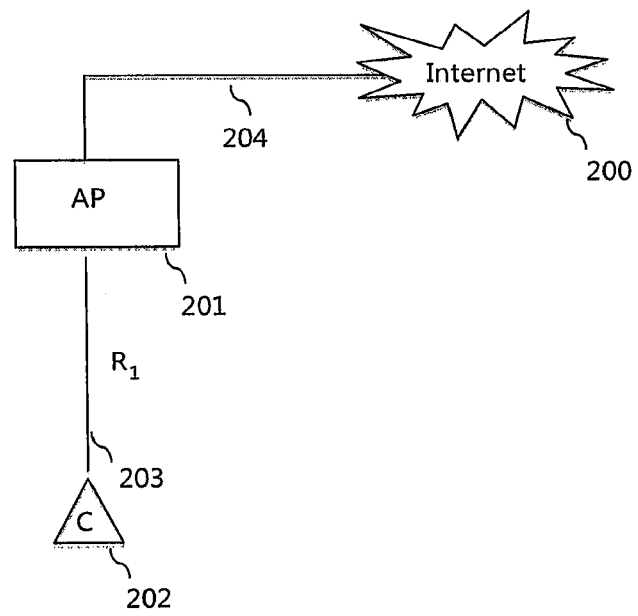


Figure 2

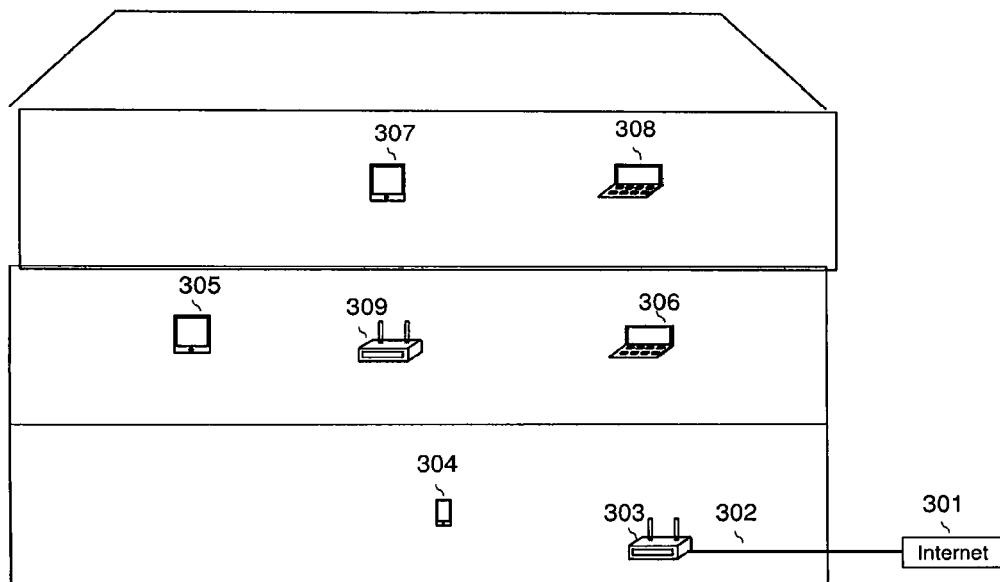


Figure 3

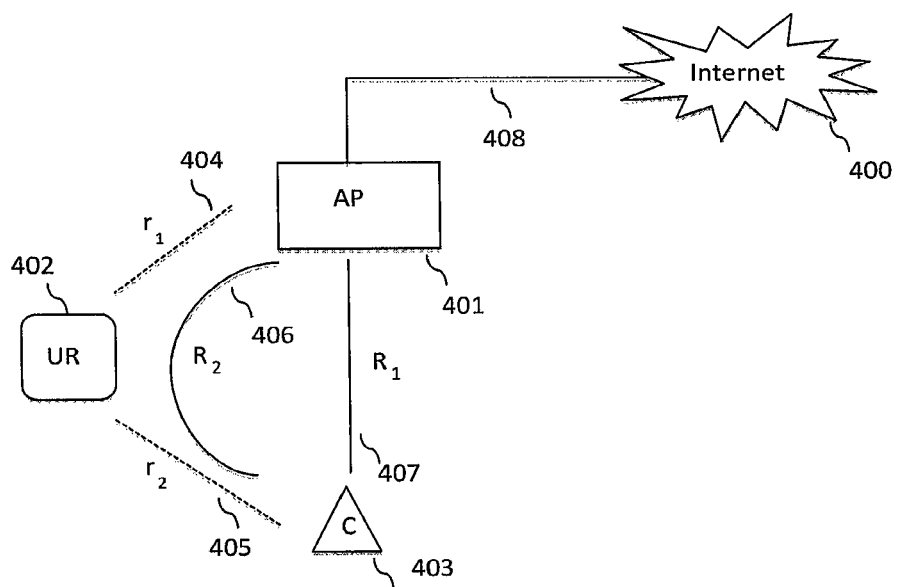


Figure 4

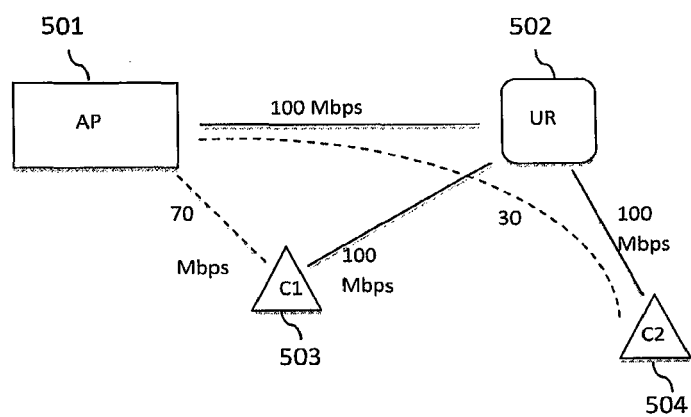


Figure 5

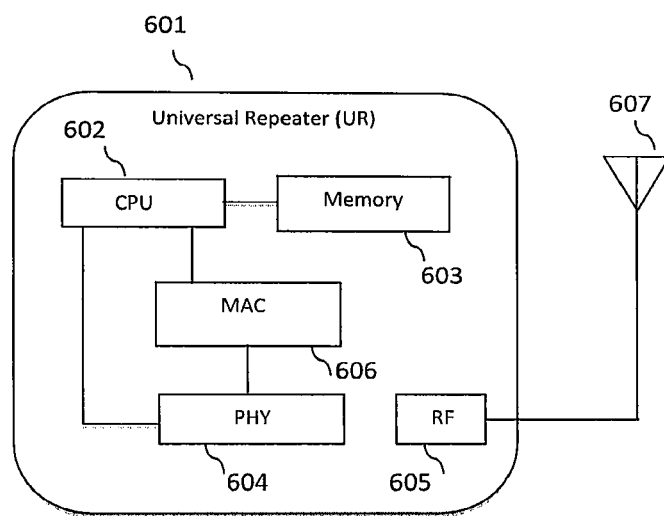


Figure 6

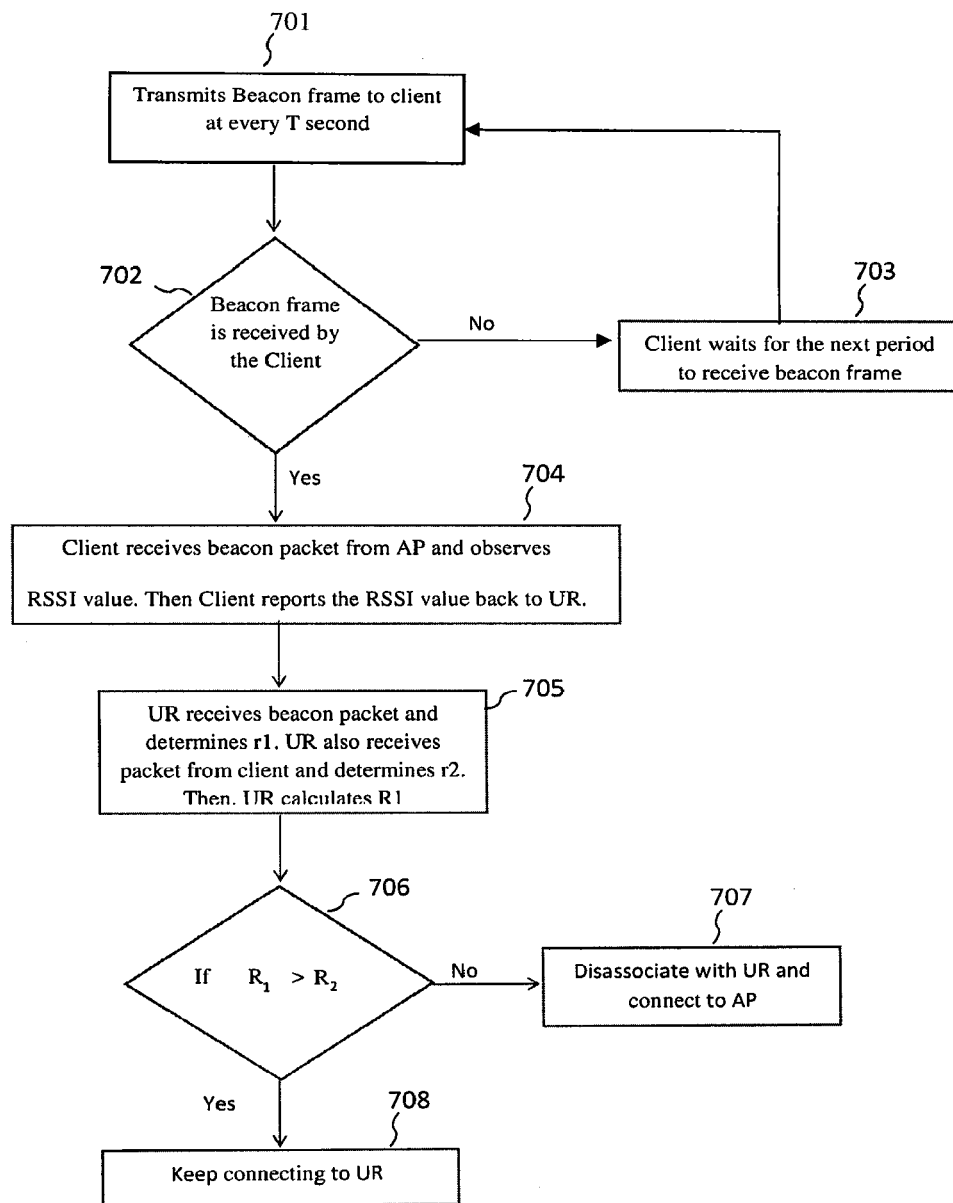


Figure 7

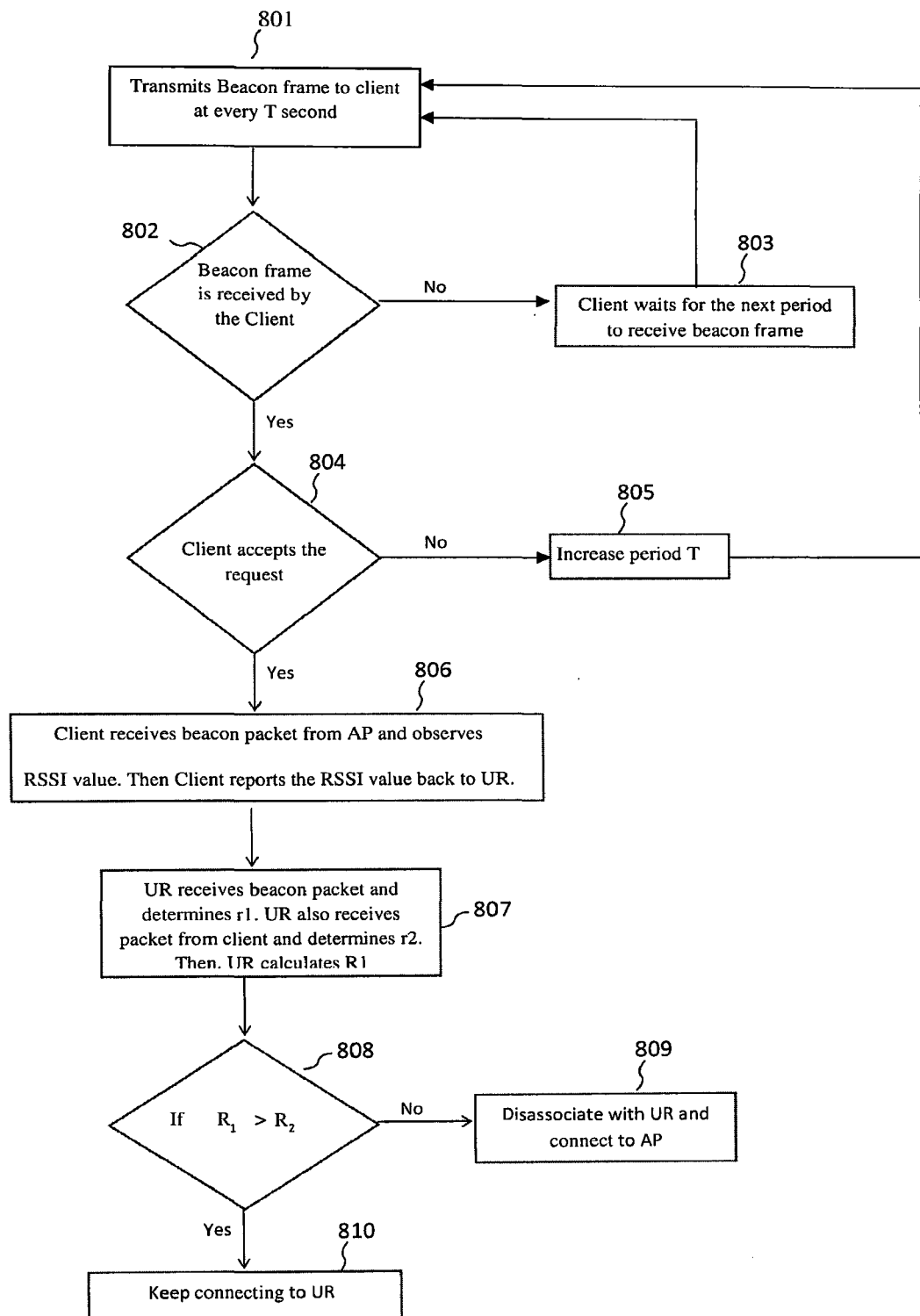


Figure 8

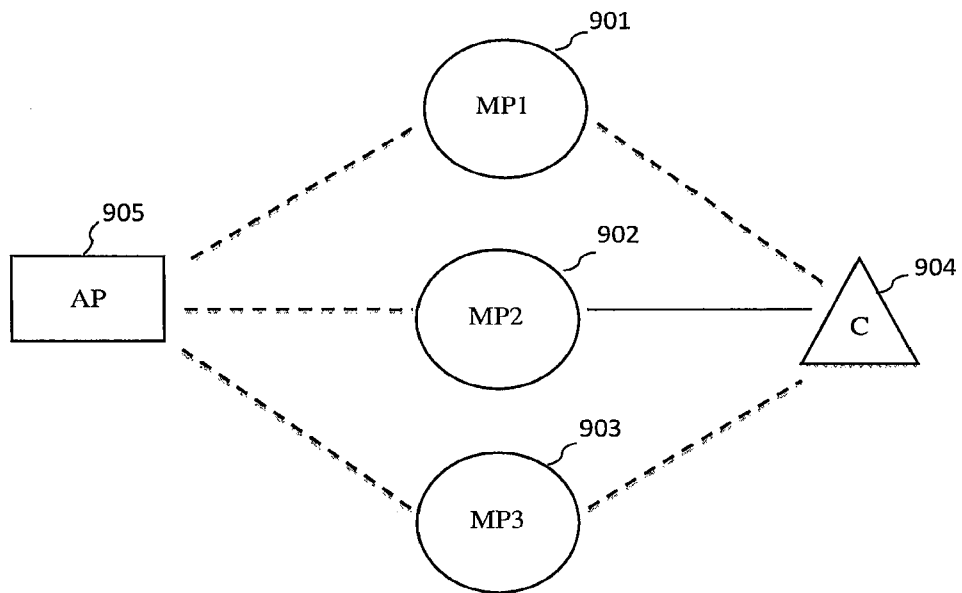


Figure 9

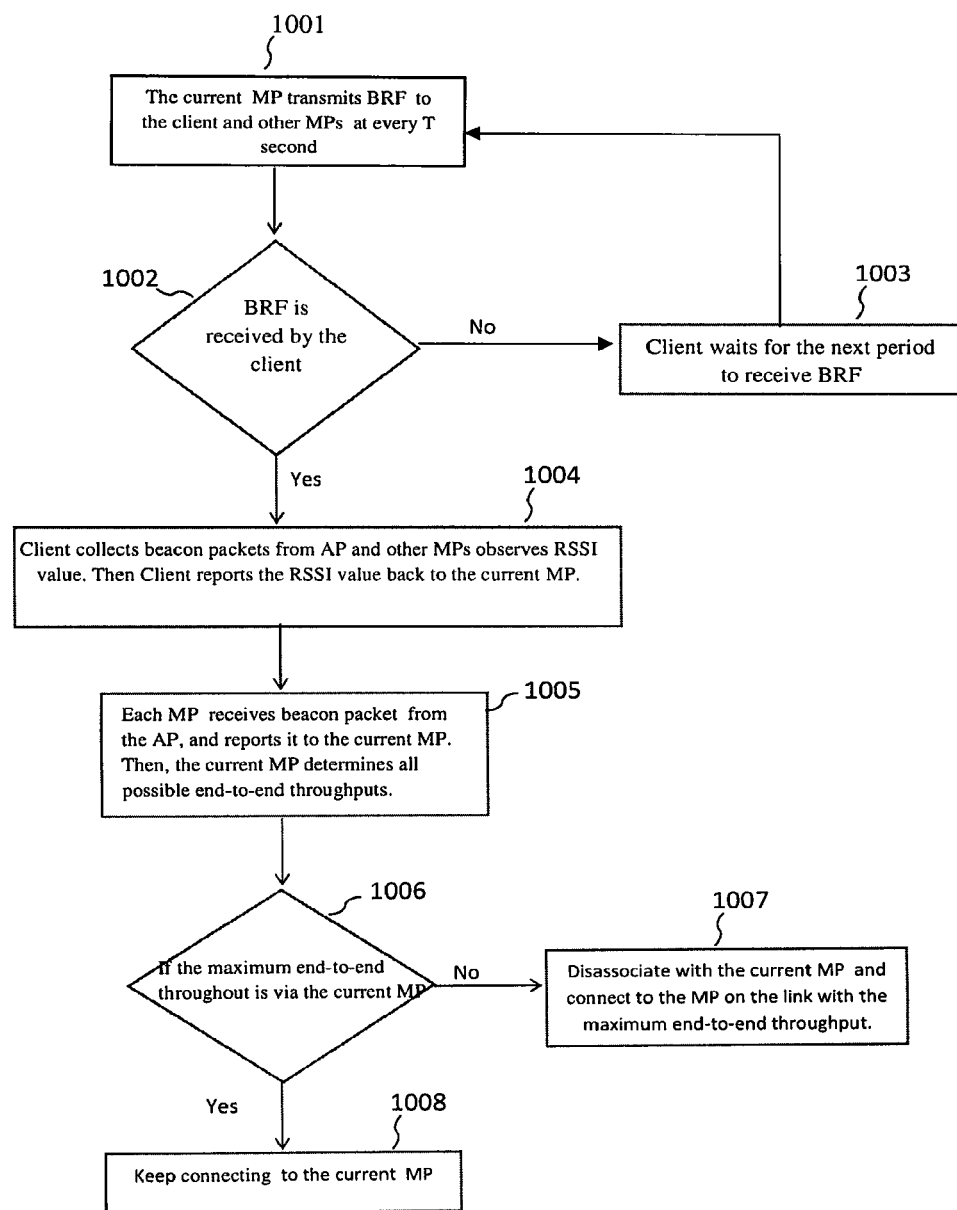


Figure 10

Brief Description of the Drawings

[0006] Figure 1 is a block diagram showing an exemplary home network where there is a single AP serving multiple clients.

[0007] Figure 2 is a simplified schematic diagram of an exemplary home network. Figure 2 depicts the transmission rates on the link between an access point and a client.

[0008] Figure 3 is a block diagram showing an exemplary home network with Universal Repeater in which aspects of the present invention can be employed;

[0009] Figure 4 is a simplified schematic diagram of an exemplary home network where there is a single client which may connect to either UR or AP.

[0010] Figure 5 shows an actual implementation of a portion of embodiment that can be seen in a typical home network, which depicts exemplary transmission rates between access point, universal repeater and client.

[0011] Figure 6 is a block diagram of the internal components of the universal repeater.

[0012] Figure 7 is a flow chart illustrating the structure of the program code executed by the universal repeater.

[0013] Figure 8 is a flow chart illustrating the structure of the program code executed by the universal repeater which includes a learning feature.

[0014] Figure 9 is a schematic diagram showing an embodiment of the invention in connection with the utilization of mesh points.

[0015] Figure 10 is a flow chart illustrating the structure of the program code executed by the Mesh Points.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0016] The exemplary wireless communication system illustrated at Fig. 1 is a typical IEEE 802.11 Wireless Local Area Network (WLAN) at homes. A WLAN consists of an Access Point (AP) 103 which may be connected to Internet 101 through a gateway. In some scenarios, there is a Wireless Router or Wireless Gateway which is connected to Internet directly as in Fig. 1. The connection between the AP and Internet may be via cable, fiber or optical 102. There may be multiple clients (e.g., stationary or mobile wireless clients) on the different floors of the home, which are connected to the AP via a different wireless connection.

[0017] The AP and the clients support the IEEE 802.11 standard (i.e., IEEE 802.11 n/ac). In a typical WLAN, the communication between the AP and a client is performed as follows: whenever AP starts operation, it transmits beacon packet periodically to announce its presence to the clients. The beacon packet is one of the management packets implemented in IEEE 802.11 based WLANs, which contains all necessary information about the network such as the modulation and coding schemes and encryption types supported by the AP. When a client receives a beacon packet from the AP, IEEE 802.11 based authentication (e.g., Wi-Fi Protected Access 1 (WPA 2)) is followed so that the attachment of the client to the WLAN is enabled. Authentication phase provides a proof of identity for the client to gain access to the WLAN. Once the client is authenticated, it associates with the AP so that the AP can deliver data to the client properly. After the association phase is completed, the client is ready to transmit/receive data to/from the AP. According to the rules in IEEE 802.11 standard and due to the limitation in the current hardware implementation a client can associate with only a single AP at a time.

[0018] Fig. 2 shows a simplified version of Fig. 1, where there is a single client associated with an AP.

[0019] In Fig. 2, wireless communication channel between the AP and the client has a highly dynamic nature due to super composed of multiple effects such as path-loss, multi-path fading and shadowing. These effects may degrade the performance of the client significantly especially high data rate transmission is required. Hence, a minimum level of signal strength at the client side must be provided so that a seamless communication with a desirable transmission rate is supported. In a home network as shown in Fig. 1, there may be multiple floors with walls, in which the effect of path-loss and fading increases dramatically. In such scenarios, the distance between the AP and the client may be too long for a direct connection to be established. For instance, in Fig.2 the transmission rate on the link between the AP and the client denoted as R_1 may be too low to support a video streaming.

[0020] In such cases, a Universal Repeater (UR) is deployed at a proper place at the home to prevent the coverage problem. Fig. 3 shows an exemplary of a home network where an UR is placed at the second floor of the home. Basically, the UR receives signal from the AP, amplifies the signal and then re-transmits it to the clients. Hence, the effect of wireless medium is mitigated. Consequently, the client receives more signal strength and the transmission with higher data rates becomes possible.

[0021] In Fig. 4 shows a simplified version of Fig. 3, where there is an AP serving a client, and an UR is placed between the AP and the client. The network illustrated in Fig. 4, the client can associate with either AP or UR but not both of them at the same time.

[0022] In the current deployment of WLANs, a client associates with the AP that has the highest signal strength. IEEE 802.11 based WLAN, the signal strength at a receiver is represented Received Signal Strength Indicator (RSSI). In this home scenario in Fig. 4, the client may associate with the UR if the RSSI value of the signal received from UR is higher than that of the AP. Although the RSSI based association performs well for one-hop transmissions, it does not always provide higher performance when the communication between the AP and the client is performed through the UR with two-hop transmission. In Fig. 4, r_1 represents the data rates between the AP and the UR and r_2 is transmission rate between the UR and the client. With a two-hop transmission in a downlink case, the client associates with the UR, and the data first is transmitted to the UR from the AP with a rate of r_1 , and then the UR amplifies the signal and retransmits it to the client with a rate of r_2 . In this two-hop transmission, the same data must be transmitted two times to be received by the client, which brings additional delay and affects the overall throughput performance. Therefore, it is important to consider the end-to-end throughput that is the throughput determined by taking into account the double transmission of the same data between the AP and the client. In Fig. 4 the end-to-end throughput between the AP and the client is denoted by R_2 , and it is determined as follows:

$$R_2 = \left(\frac{1}{r_1} + \frac{1}{r_2} \right)^{-1}$$

[0023] In Fig. 4, R_1 represents the transmission rate on the direct link between the AP and the client, and if the client associates with the AP it achieves data rate of R_1 .

[0024] Fig. 5 depicts an exemplary scenario where there are two clients that may associate either with the AP or the UR depending on their end-to-end throughput results. If Client 1 denoted as C_1 associates with the AP directly (i.e., one-hop transmission), it achieves 70 Mbps amount of throughput. The data rates on the links between C_1 and the UR and the UR and the AP are equal to 100 Mbps, i.e., $r_1 = r_2 = 100$ Mbps. After applying equation (1) the end-to-end throughput of C_1 is equal to 33.33 Mbps. That means if C_1 associates with the UR it achieves 33.33 Mbps but not 100 Mbps. Therefore, by considering the end-to-end throughput, for C_1 it is more beneficial to associate with the AP directly instead of associating with the UR.

[0025] If Client 2 denoted as C_2 in Fig. 5 associates with the AP, its throughput is equal to 30 Mbps. The end-to-end throughput between C_2 and the AP can be calculated in a similar way as that of the end-to-end throughput of C_1 , and it is equal to 33.33 Mbps, which is higher than the direct transmission rate. Hence, unlike C_1 , for C_2 it is more beneficial to associate with the UR instead of associating with the AP.

[0026] In one embodiment of the invention, the association decision of the clients are given by the UR. To give the best decision that maximizes the throughput of the clients, the UR has to know all the transmission rates, r_1, r_2, R_1 , which necessitates that all the corresponding RSSI values should be measured and collected by the UR. The IEEE 802.11k standard which is an extension to the IEEE 802.11 has been developed to provide measurement information

for APs to make an efficient radio resource management realizable. Within the 802.11k standard, various types of measurements are defined, and the measured data can be used by an AP for the optimization of the network performance (i.e., the optimal channel selection, the transmit power). In the 802.11k, the measurements are performed with request/response frame exchanges, and the radio resource measurements defined in IEEE 802.11k includes the following measurement reports:

a- Beacon Request/Response Frame enables an AP to request a client to report a set of beacon packets it receives on a specified channels. Either active or passive scanning may be used for measurement. Logged collected beacon packets is reported back to the AP without requiring further measurement. Beacon Report providing RSSI values, BSSID (Basic Service Set identification), beacon interval and additional parameters which are based on detected beacon or probe responses.

b- Channel load Request/Response Frame may be used to determine the channel with the minimum traffic load.

c-Receive Power Indication Report indicating received power levels on a measured channel.

d-Channel Load Report providing the proportion of time for which the measuring wireless station determined the channel to be busy, i.e. the time which physical carrier sense or the Network Allocation Vector (NAV) indicated busy.

e- Noise Histogram Report including non-802.11 energy for the requested channel by sampling the channel when CCA (Clear Channel Assessment) indicates idle. The report includes the RPI (Received Power Indicator) densities observed in the channel for eight specified RPI levels.

f- Frame Report providing a summary of traffic from one transmit address and contains number of frames, RCPI and BSSID and transmit address.

g-STA statistics Report indicating the change in STA counters within a specified measurement duration.

h-Link Measurement Report includes link path loss and estimation of link margin.

[0027] In one embodiment of the invention the UR uses Beacon Request/Response Frames implemented in IEEE 802.11k standard which shall be supported by the UR and the client. However, the AP does not necessarily support it.

[0028] In one embodiment of the invention, the client may not support 802.11k standard. In this case, the UR sends 802.11k packets to the AP and in return the AP performs the necessary measurements. In the latter case, the UR and the AP supports IEEE 802.11k standard but the client does not necessarily support it.

[0028] Fig. 7 is a flow chart illustrating a basic method for the invention implemented at the UR. The proposed method is based on the scenario given in Fig. 4. The implementing our invention to more complex scenarios where there are multiple clients and APs can be performed in a similar way.

[0029] In Fig. 7 at step 701 our method starts and there are two possibilities for the method to be triggered. In one embodiment of the invention a periodic trigger is employed, where the method is performed at every T seconds, where T is the period of the measurements which are realized to gather the all necessary RSSI values.

[0030] In one embodiment of the invention, the method may be triggered based on the control of the UR, whenever the UR detects a need for the measurement.

[0031] At step 701, the UR transmits a Beacon Request Frame (BRqF) defined in 802.11k to the client. If more than one AP operating different, the UR may specify the channels that the client must measure. At step 702, it must be ensured that the BRqF transmitted by the UR is received by the client correctly. If the BRqF is received correctly by the client, the client goes to the next step 704 and starts measurement process. Otherwise, the client waits for the next period. The unsuccessful transmission of the BRqF may be because of the harmful effect of the wireless channel or the collision caused by the transmission of other clients or AP.

[0031] At step 704 after receiving and decoding the BRqF successfully, then the client disconnects from the UR and starts measurement phase where it collects beacon packets that it receives from the AP. The beacon packets transmitted by the AP contain information about the RSSI value which is used to determine the transmission rate on the link between the AP and the client. Then, the client prepares Beacon Report Frame that contains the MAC address and operating channel of the AP, and the corresponding RSSI value. After preparing the report, the client switches the channel on which the UR operates, and the report is sent back to the UR. In an exemplary embodiment of the invention, there may be multiple APs operating different channels. For this case, the client measures each channel, and collects beacon packet from each AP operating on those channels. Then, the Beacon Report Frame contains all MAC addresses and the operating channels of the APs, and the corresponding RSSI values as well.

[0032] At step 705, after receiving the RSSI value then the UR is able to determine the direct transmission rate on the link between the client and the AP denoted as R_1 . To calculate the end-to-end rate denoted as R_2 , the UR has to know r_1 and r_2 . At step 705, the UR listens the channel, and receives beacon packets from the AP. By using the received beacon packet of the AP, the UR first observes the RSSI value of the signal coming from the AP, and then determines the transmission rate, r_1 . Next, the UR determines the rate on the link between the client and itself, r_2 . The RSSI value of the signal coming from the client allows the UR to calculate rate r_2 . Finally, the UR observes all the rates, r_1 , r_2 , R_1 . The end-to-end transmission rate R_2 is calculated by applying equation (1).

[0033] At step 706, the UR decides whether two-hop transmission via the UR or one-hop transmission is more beneficial for the client in terms of throughput. At step 706, this decision is given by the UR by comparing the rates R_1 and R_2 . If the transmission rate R_1 is higher than the end-to-end throughput R_2 , then associating with the AP provides more throughput for the client. Hence, at step 707, the UR transmits disassociation frame to the client, and the client disconnects from the UR, and it associates with the AP. If the end-to-end transmission rate R_2 is higher than the rate on the direct transmission rate R_1 then the client keeps associating with the UR.

[0034] In an exemplary embodiment of the invention, the client may not wish to response for every BRqF. This is because of preventing frequent disconnection of the communication

between the UR and the client. This is particularly important when the client has delay constrained application such as Voice over IP.

[0035] Fig. 8 is a flow chart illustrating the improvements for the method described in Fig. 7. Basically, there are two main improvements on our method that are explained in the following paragraphs. At step 801 the trigger of the new method may be periodic, where at every T seconds the UR transmits BRqF to the client to gather information on the quality of the link between the AP and the client. At step 802, the UR checks whether the BRqF is received and accepted by the client. If it is accepted, then the client performs the next step 804. If the BRqF is not accepted by the client, the duration T is too large for the client, and the client is not willing to perform measurement for a large value of T . Then, at step 803, the UR decreases T , and specifies the new value of T in the next BRqF, which is transmitted to the client in the next round. If the client accepts this new value of T , then the next step 804 is performed. Otherwise, the UR keeps decreasing T until the client accepts it. When the client accepts the period T , it starts the required measurement. First, it disconnects from the UR and collects beacon packets that it receives from the other AP operating in the specified channels. In those beacon packets that the client collects contain information regarding the RSSI values of each AP that the client hears. Then, the client prepares report frame that contains the MAC address of the APs that the client hears, the operating channels of these AP and the corresponding RSSI values. After preparing the report, the client switches the channel on which the UR operates, and the report is sent back to the UR.

[0035] At step 805, after receiving the RSSI values then the UR is able to determine the direct transmission rate on the link between the client and the AP, R_1 . To calculate the end-to-end rate R_2 , the UR has to know r_1 and r_2 . To do that, at step 805, the UR listens the channel, and receives beacon packets from the AP. By using the received beacon packet of the AP, the UR first observes the RSSI value of the signal coming from the AP, and then determines the transmission rate R_1 . Next, the UR determines the rate on the link between the client and itself, R_2 . The RSSI value of the signal coming from the client allows the UR to calculate rate R_2 . Finally, the UR observes all the rates, r_1 , r_2 and R_1 . The end-to-end transmission rate R_2 is calculated by applying equation (1).

[0036] To provide the client to have the maximum throughput, the UR decides whether the client associated with the AP or itself. At step 806, this decision is given by the UR by comparing the rates R_1 and R_2 . In one embodiment of the invention, if the difference between the rates R_1 and R_2 is not too much, the client may not wish to experience frequent association/disassociations. Therefore, in this embodiment of the invention, a threshold based association scheme is employed, where the client association is performed only if the difference between R_1 and R_2 is higher than a pre-defined threshold. If the difference between R_1 and R_2 is higher than the threshold then for the client associating with the AP is more beneficial in terms of the maximum achievable throughput. Hence, at step 807, the UR transmits disassociation frame to the client, and the client disconnects from the UR, and it associates with the AP. Otherwise, the client keeps associating with the UR.

[0037] Fig 6. is a block diagram showing an example of a hardware configuration of the UR. The UR has a CPU, a memory, Medium Access Control (MAC) chip, a Radio Frequency Chip (RF) with antennas. These elements are connected by a bus that is possible for a bidirectional data communication. The CPU reads program from the memory and realizes

various functions of the UR. The memory temporary stores the data, which is required during the execution of the program. The CPU and the memory can be configured as separate or can be configured as one.

[0038] In Fig. 6, wireless communication is realized by MAC and RF chip. At MAC chip, the clients and the AP access to the wireless medium in the pre-defined rules which are defined according to the IEEE 802.11 standard. At RF chip, the data packets are converted to radio waves and are transmitted to the wireless medium via antennas. The invention is implemented at MAC chip via a software program that can be easily deployed at any MAC chip with the capability of IEEE 802.11k standard.

[0039] Different from deploying an UR at homes, another way to mitigate the bad effect of the wireless medium and to extend the coverage of wireless network is using multiple APs to create a wireless mesh network, and to deliver data over this mesh network. However, although the coverage is extended significantly, since the wireless mesh points (MPs) use the same limited wireless medium, the available capacity is shared among all mesh points, which may cause some level of decrease in the end-to-end throughput of a client as in the case of using an UR.

[0040] Although an UR just amplifies and retransmits an incoming signal, a MP can decide more intelligent decision such as routing in which it can change the direction of the communication according to some required constraints. For instance a MP can transmit data over the path which will provide the minimum contention or the maximum throughput. However, a client usually associates with the closet MP since its RSSI is higher than other MPs in the network. Hence, the end-end throughput does not usually taken into account when association decision is given, which causes the same inefficiency problem occurred in the network where UR are used for range extension.

[0041] Fig. 9 shows an example network where mesh points denoted as MPs are connected to the AP wirelessly. Also, the clients may connect the MPs via wireless connections, or they may connect to the AP directly without communication with the MPs. For a downlink scenario, the client receives data from the AP through MPs, where the clients' data first arrives into one of the MP, then that MP transmits the data to the clients. For uplink scenario, the clients wish to transmit data to the AP or gateway. The client may transmit directly to the AP or to a MP. Then, that MP transmits data to the AP wirelessly. For both downlink and uplink scenarios, the end-to-end throughput between the client and the AP should be taken account, and the decision of the client association is given with the knowledge of the end-to-end transmission rate.

[0042] Fig. 10 is a flow chart illustrating a basic method for the invention implemented at the MPs. At step 1001, the current MP with which the client is associated transmits BRqF to the client and the other MPs. If the BRqF is not received by any of MPs or the client, the MP keeps transmitting BRqF until all other MPs and the client accept it.

[0043] At step 1004, the client collects beacon packets that it receives from other MPs and the AP, and observes the corresponding RSSI values. Then, the client prepares 802.11k Beacon Request Reports which contains the information about the received beacon packets with the corresponding RSSI values, and sends it to the current MP.

[0044] At step 1005, the other MPs also collect beacon packets that they receive from the AP, and report it to the current MP.

[0044] At step 1006, the MP determines all possible end-to-end throughput on each link between the AP and the client by using the gathered transmission rates at step 1004 and step 1005.

[0045] At step 1007, the current MP determines the best link with the maximum end-to-end throughput is observed. If the current MP involves with the best link, then the client keeps connecting to the current MP.

[0046] The best link may not always involve with the current MP. In this case, the client shall associate with the MP that involves with the best link. To do that first, the current MP determines the MP which involves with the best link. In the next phase, the current MP needs to inform the client about the new MP with the maximum end-to-end throughput. In one embodiment of the invention, 802.11v packets are used to inform client devices in a standard-compliant manner. Other standard-compliant methods or proprietary ones may be used to convey the same information. 802.11v provides the wireless resource management enhancements to 802.11. While 802.11k provides the frames to gather useful network information by measuring, 802.11v enables the ability of configuring the clients. IEEE 802.11v standard includes the following special frame:

- Association Request Frame (ARF): In an ARF, an AP specifies one or more MAC addresses of the candidates APs with which a client may associate.

[0047] If the link with the maximum end-to-end throughput contains a different MP from the current MP, the current MP sends ARF to the client by indicating the MP which is on the link with the maximum end-to-end throughput.

[0048] After the client receiving ARF, it disassociates with the current MP, and associates with the MP indicated within the ARF.

Field of the Invention

[0001] The present invention generally relates to wireless networking, more particularly, to a mechanism for a wireless client of a wireless network to select an access point for data transmission according to the end-to-end throughput performance when there are universal repeater and wireless mesh points in wireless communication networks. For client association the proposed invention utilizes the special packets defined within IEEE 802.11k and 802.11v standards.

Background of the Invention

[0002] IEEE 802.11 based Wireless Local Area Networks (WLANs) have been deployed in many places such as at homes, schools, hospitals and cafes as they enable us to reach digital information with a great flexibility and low-cost. However, due to harmful effects of wireless medium such as walls between transmitter and receiver and fading the throughput achieved by the clients in WLAN may be too low. Furthermore, a client may experience some level of disconnection from the AP. This is known as wireless coverage problem which causes distortion in the wireless communication between clients and the APs. Hence, it is important to find efficient and low-cost methods which provide full connectivity in WLANs by extending the range. One solution is to increase transmit power of the transmitting nodes in the network. However, this solution is not an efficient for two main reasons: first reason is that increasing transmit power causes more energy consumption. The second reason is that higher transmit power generates more interference in the network. An efficient solution is to transmit a signal with two-hop fashion by using a second transmitter instead of single-hop transmission with which the signal is transmitted directly to the receiver.

[0003] For a WLAN, two possible ways which enable two-hop transmission to mitigate the coverage problem are given as follows; first solution is to retransmit the signal by an Universal Repeater which is deployed at a proper place in WLAN. The second solution is to build a wireless mesh network by using multiple Mesh Points (MPs), and the data of a client reaches to the gateway by using these mesh points via wireless connection.

[0004] In both of these scenarios, usually a client associates with the closest transmitter that provides the maximum signal strength. However, the signal strength based association may be sub optimal solution for two-hop transmission in terms of throughput performance, and may degrade the overall throughput of the network significantly. This degradation is basically due to the fact that two-hop transmission necessitates the double transmission of the same data, which brings some additional delay, and reduce throughput. In most current implementations of two-hop transmission schemes, a client is aware of only the transmission rate at only one side of the two-hop transmission, which is the transmission rate between the UR or a MP and itself. However, the client is not aware of the transmission rate between the UR or a MP and the wireless gateway. Although transmission rate at one-side of a two-hop transmission is high, the rate at the other side may reduce the overall rate which is the end-to-end transmission rate of the client. Hence, the two-hop transmission may not always result in

a higher throughput. To achieve the best performance the end-to-end transmission rate of a client must be obtained and the client association must be performed with this rate.

[0005] In one embodiment of the invention a new association scheme for clients in a WLAN with an UR is proposed. Our invention utilizes a special packet implemented within the IEEE 802.11k standard. In the invention, UR determines whether one-hop or two-hop transmission via the UR provides the maximum throughput for clients.

[0006] In one embodiment of the invention client association within a mesh network is presented by taking into account the end-to-end throughput performance and using particular packets implemented in IEEE 802.11k and 802.11v standards.

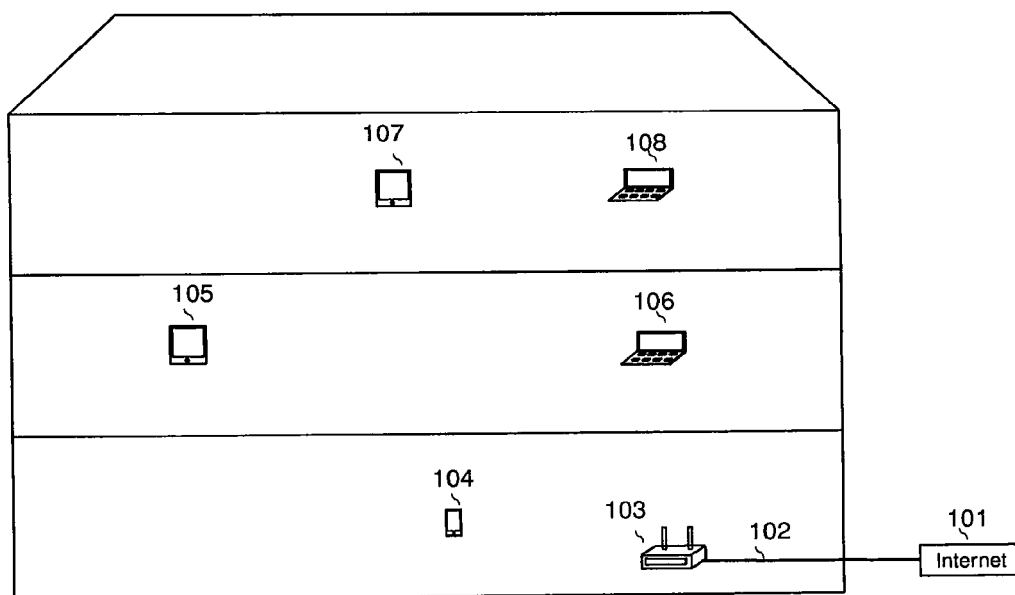


Figure 1

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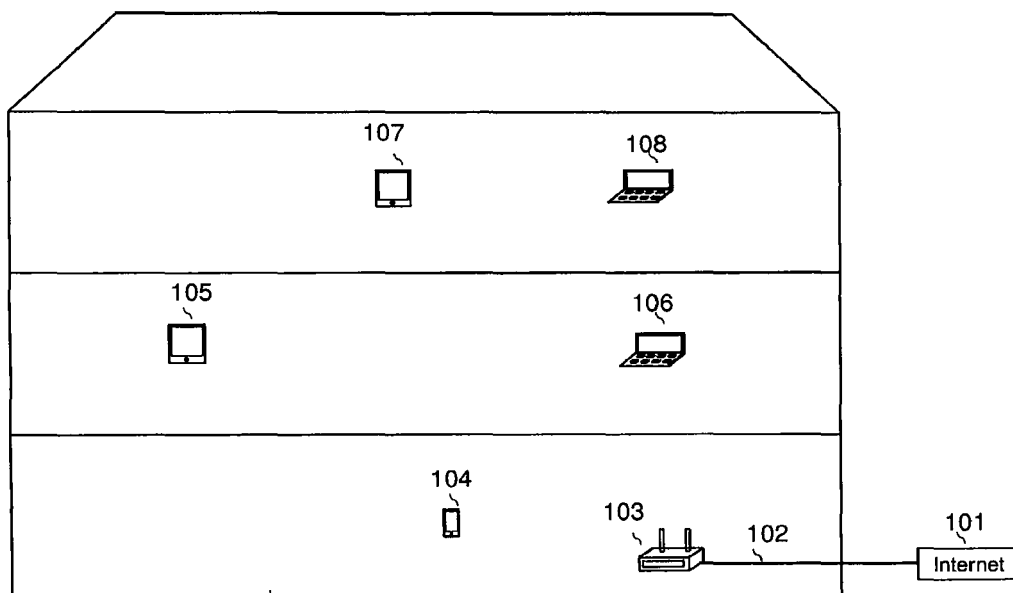


Figure 1

Electronic Acknowledgement Receipt

EFS ID:	19382856
Application Number:	62015853
International Application Number:	
Confirmation Number:	7666
Title of Invention:	SMART UR
First Named Inventor/Applicant Name:	Mehmet KARACA
Customer Number:	30593
Filer:	John A. Castellano III
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Document Description	Start	End
Provisional Cover Sheet (SB16)	1	2
Application Data Sheet	3	8
Specification	9	27
Drawings-only black and white line drawings	28	46

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2	Fee Worksheet (SB06)	fee-info.pdf	29110 c375065a43ac1b887d6a0c8a4edc2d1a46cfa d5d3d	no	2
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Brief Description of the Drawings

[0006] Figure 1 is a block diagram showing an exemplary home network where there is a single AP serving multiple clients.

[0007] Figure 2 is a simplified schematic diagram of an exemplary home network. Figure 2 depicts the transmission rates on the link between an access point and a client.

[0008] Figure 3 is a block diagram showing an exemplary home network with Universal Repeater in which aspects of the present invention can be employed;

[0009] Figure 4 is a simplified schematic diagram of an exemplary home network where there is a single client which may connect to either UR or AP.

[0010] Figure 5 shows an actual implementation of a portion of embodiment that can be seen in a typical home network, which depicts exemplary transmission rates between access point, universal repeater and client.

[0011] Figure 6 is a block diagram of the internal components of the universal repeater.

[0012] Figure 7 is a flow chart illustrating the structure of the program code executed by the universal repeater.

[0013] Figure 8 is a flow chart illustrating the structure of the program code executed by the universal repeater which includes a learning feature.

[0014] Figure 9 is a schematic diagram showing an embodiment of the invention in connection with the utilization of mesh points.

[0015] Figure 10 is a flow chart illustrating the structure of the program code executed by the Mesh Points.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0016] The exemplary wireless communication system illustrated at Fig. 1 is a typical IEEE 802.11 Wireless Local Area Network (WLAN) at homes. A WLAN consists of an Access Point (AP) 103 which may be connected to Internet 101 through a gateway. In some scenarios, there is a Wireless Router or Wireless Gateway which is connected to Internet directly as in Fig. 1. The connection between the AP and Internet may be via cable, fiber or optical 102. There may be multiple clients (e.g., stationary or mobile wireless clients) on the different floors of the home, which are connected to the AP via a different wireless connection.

[0017] The AP and the clients support the IEEE 802.11 standard (i.e., IEEE 802.11 n/ac). In a typical WLAN, the communication between the AP and a client is performed as follows: whenever AP starts operation, it transmits beacon packet periodically to announce its presence to the clients. The beacon packet is one of the management packets implemented in IEEE 802.11 based WLANs, which contains all necessary information about the network such as the modulation and coding schemes and encryption types supported by the AP. When a client receives a beacon packet from the AP, IEEE 802.11 based authentication (e.g., Wi-Fi Protected Access 1 (WPA 2)) is followed so that the attachment of the client to the WLAN is enabled. Authentication phase provides a proof of identity for the client to gain access to the WLAN. Once the client is authenticated, it associates with the AP so that the AP can deliver data to the client properly. After the association phase is completed, the client is ready to transmit/receive data to/from the AP. According to the rules in IEEE 802.11 standard and due to the limitation in the current hardware implementation a client can associate with only a single AP at a time.

[0018] Fig. 2 shows a simplified version of Fig. 1, where there is a single client associated with an AP.

[0019] In Fig. 2, wireless communication channel between the AP and the client has a highly dynamic nature due to super composed of multiple effects such as path-loss, multi-path fading and shadowing. These effects may degrade the performance of the client significantly especially high data rate transmission is required. Hence, a minimum level of signal strength at the client side must be provided so that a seamless communication with a desirable transmission rate is supported. In a home network as shown in Fig. 1, there may be multiple floors with walls, in which the effect of path-loss and fading increases dramatically. In such scenarios, the distance between the AP and the client may be too long for a direct connection to be established. For instance, in Fig.2 the transmission rate on the link between the AP and the client denoted as R_1 may be too low to support a video streaming.

[0020] In such cases, a Universal Repeater (UR) is deployed at a proper place at the home to prevent the coverage problem. Fig. 3 shows an exemplary of a home network where an UR is placed at the second floor of the home. Basically, the UR receives signal from the AP, amplifies the signal and then re-transmits it to the clients. Hence, the effect of wireless medium is mitigated. Consequently, the client receives more signal strength and the transmission with higher data rates becomes possible.

[0021] In Fig. 4 shows a simplified version of Fig. 3, where there is an AP serving a client, and an UR is placed between the AP and the client. The network illustrated in Fig. 4, the client can associate with either AP or UR but not both of them at the same time.

[0022] In the current deployment of WLANs, a client associates with the AP that has the highest signal strength. IEEE 802.11 based WLAN, the signal strength at a receiver is represented Received Signal Strength Indicator (RSSI). In this home scenario in Fig. 4, the client may associate with the UR if the RSSI value of the signal received from UR is higher than that of the AP. Although the RSSI based association performs well for one-hop transmissions, it does not always provide higher performance when the communication between the AP and the client is performed through the UR with two-hop transmission. In Fig. 4, r_1 represents the data rates between the AP and the UR and r_2 is transmission rate between the UR and the client. With a two-hop transmission in a downlink case, the client associates with the UR, and the data first is transmitted to the UR from the AP with a rate of r_1 , and then the UR amplifies the signal and retransmits it to the client with a rate of r_2 . In this two-hop transmission, the same data must be transmitted two times to be received by the client, which brings additional delay and affects the overall throughput performance. Therefore, it is important to consider the end-to-end throughput that is the throughput determined by taking into account the double transmission of the same data between the AP and the client. In Fig. 4 the end-to-end throughput between the AP and the client is denoted by R_2 , and it is determined as follows:

$$R_2 = \left(\frac{1}{r_1} + \frac{1}{r_2} \right)^{-1}$$

[0023] In Fig. 4, R_1 represents the transmission rate on the direct link between the AP and the client, and if the client associates with the AP it achieves data rate of R_1 .

[0024] Fig. 5 depicts an exemplary scenario where there are two clients that may associate either with the AP or the UR depending on their end-to-end throughput results. If Client 1 denoted as C_1 associates with the AP directly (i.e., one-hop transmission), it achieves 70 Mbps amount of throughput. The data rates on the links between C_1 and the UR and the UR and the AP are equal to 100 Mbps, i.e., $r_1 = r_2 = 100$ Mbps. After applying equation (1) the end-to-end throughput of C_1 is equal to 33.33 Mbps. That means if C_1 associates with the UR it achieves 33.33 Mbps but not 100 Mbps. Therefore, by considering the end-to-end throughput, for C_1 it is more beneficial to associate with the AP directly instead of associating with the UR.

[0025] If Client 2 denoted as C_2 in Fig. 5 associates with the AP, its throughput is equal to 30 Mbps. The end-to-end throughput between C_2 and the AP can be calculated in a similar way as that of the end-to-end throughput of C_1 , and it is equal to 33.33 Mbps, which is higher than the direct transmission rate. Hence, unlike C_1 , for C_2 it is more beneficial to associate with the UR instead of associating with the AP.

[0026] In one embodiment of the invention, the association decision of the clients are given by the UR. To give the best decision that maximizes the throughput of the clients, the UR has to know all the transmission rates, r_1 , r_2 , R_1 , which necessitates that all the corresponding RSSI values should be measured and collected by the UR. The IEEE 802.11k standard which is an extension to the IEEE 802.11 has been developed to provide measurement information

for APs to make an efficient radio resource management realizable. Within the 802.11k standard, various types of measurements are defined, and the measured data can be used by an AP for the optimization of the network performance (i.e., the optimal channel selection, the transmit power). In the 802.11k, the measurements are performed with request/response frame exchanges, and the radio resource measurements defined in IEEE 802.11k includes the following measurement reports:

a- Beacon Request/Response Frame enables an AP to request a client to report a set of beacon packets it receives on a specified channels. Either active or passive scanning may be used for measurement. Logged collected beacon packets is reported back to the AP without requiring further measurement. Beacon Report providing RSSI values, BSSID (Basic Service Set identification), beacon interval and additional parameters which are based on detected beacon or probe responses.

b- Channel load Request/Response Frame may be used to determine the channel with the minimum traffic load.

c-Receive Power Indication Report indicating received power levels on a measured channel.

d-Channel Load Report providing the proportion of time for which the measuring wireless station determined the channel to be busy, i.e. the time which physical carrier sense or the Network Allocation Vector (NAV) indicated busy.

e- Noise Histogram Report including non-802.11 energy for the requested channel by sampling the channel when CCA (Clear Channel Assessment) indicates idle. The report includes the RPI (Received Power Indicator) densities observed in the channel for eight specified RPI levels.

f- Frame Report providing a summary of traffic from one transmit address and contains number of frames, RCPI and BSSID and transmit address.

g-STA statistics Report indicating the change in STA counters within a specified measurement duration.

h-Link Measurement Report includes link path loss and estimation of link margin.

[0027] In one embodiment of the invention the UR uses Beacon Request/Response Frames implemented in IEEE 802.11k standard which shall be supported by the UR and the client. However, the AP does not necessarily support it.

[0028] In one embodiment of the invention, the client may not support 802.11k standard. In this case, the UR sends 802.11k packets to the AP and in return the AP performs the necessary measurements. In the latter case, the UR and the AP supports IEEE 802.11k standard but the client does not necessarily support it.

[0028] Fig. 7 is a flow chart illustrating a basic method for the invention implemented at the UR. The proposed method is based on the scenario given in Fig. 4. The implementing our invention to more complex scenarios where there are multiple clients and APs can be performed in a similar way.

[0029] In Fig. 7 at step 701 our method starts and there are two possibilities for the method to be triggered. In one embodiment of the invention a periodic trigger is employed, where the method is performed at every T seconds, where T is the period of the measurements which are realized to gather the all necessary RSSI values.

[0030] In one embodiment of the invention, the method may be triggered based on the control of the UR, whenever the UR detects a need for the measurement.

[0031] At step 701, the UR transmits a Beacon Request Frame (BRqF) defined in 802.11k to the client. If more than one AP operating different, the UR may specify the channels that the client must measure. At step 702, it must be ensured that the BRqF transmitted by the UR is received by the client correctly. If the BRqF is received correctly by the client, the client goes to the next step 704 and starts measurement process. Otherwise, the client waits for the next period. The unsuccessful transmission of the BRqF may be because of the harmful effect of the wireless channel or the collision caused by the transmission of other clients or AP.

[0031] At step 704 after receiving and decoding the BRqF successfully, then the client disconnects from the UR and starts measurement phase where it collects beacon packets that it receives from the AP. The beacon packets transmitted by the AP contain information about the RSSI value which is used to determine the transmission rate on the link between the AP and the client. Then, the client prepares Beacon Report Frame that contains the MAC address and operating channel of the AP, and the corresponding RSSI value. After preparing the report, the client switches the channel on which the UR operates, and the report is sent back to the UR. In an exemplary embodiment of the invention, there may be multiple APs operating different channels. For this case, the client measures each channel, and collects beacon packet from each AP operating on those channels. Then, the Beacon Report Frame contains all MAC addresses and the operating channels of the APs, and the corresponding RSSI values as well.

[0032] At step 705, after receiving the RSSI value then the UR is able to determine the direct transmission rate on the link between the client and the AP denoted as R_1 . To calculate the end-to-end rate denoted as R_2 , the UR has to know r_1 and r_2 . At step 705, the UR listens the channel, and receives beacon packets from the AP. By using the received beacon packet of the AP, the UR first observes the RSSI value of the signal coming from the AP, and then determines the transmission rate, r_1 . Next, the UR determines the rate on the link between the client and itself, r_2 . The RSSI value of the signal coming from the client allows the UR to calculate rate r_2 . Finally, the UR observes all the rates, r_1 , r_2 , R_1 . The end-to-end transmission rate R_2 is calculated by applying equation (1).

[0033] At step 706, the UR decides whether two-hop transmission via the UR or one-hop transmission is more beneficial for the client in terms of throughput. At step 706, this decision is given by the UR by comparing the rates R_1 and R_2 . If the transmission rate R_1 is higher than the end-to-end throughput R_2 , then associating with the AP provides more throughput for the client. Hence, at step 707, the UR transmits disassociation frame to the client, and the client disconnects from the UR, and it associates with the AP. If the end-to-end transmission rate R_2 is higher than the rate on the direct transmission rate R_1 then the client keeps associating with the UR.

[0034] In an exemplary embodiment of the invention, the client may not wish to response for every BRqF. This is because of preventing frequent disconnection of the communication

between the UR and the client. This is particularly important when the client has delay constrained application such as Voice over IP.

[0035] Fig. 8 is a flow chart illustrating the improvements for the method described in Fig. 7. Basically, there are two main improvements on our method that are explained in the following paragraphs. At step 801 the trigger of the new method may be periodic, where at every T seconds the UR transmits BRqF to the client to gather information on the quality of the link between the AP and the client. At step 802, the UR checks whether the BRqF is received and accepted by the client. If it is accepted, then the client performs the next step 804. If the BRqF is not accepted by the client, the duration T is too large for the client, and the client is not willing to perform measurement for a large value of T . Then, at step 803, the UR decreases T , and specifies the new value of T in the next BRqF, which is transmitted to the client in the next round. If the client accepts this new value of T , then the next step 804 is performed. Otherwise, the UR keeps decreasing T until the client accepts it. When the client accepts the period T , it starts the required measurement. First, it disconnects from the UR and collects beacon packets that it receives from the other AP operating in the specified channels. In those beacon packets that the client collects contain information regarding the RSSI values of each AP that the client hears. Then, the client prepares report frame that contains the MAC address of the APs that the client hears, the operating channels of these AP and the corresponding RSSI values. After preparing the report, the client switches the channel on which the UR operates, and the report is sent back to the UR.

[0035] At step 805, after receiving the RSSI values then the UR is able to determine the direct transmission rate on the link between the client and the AP, R_1 . To calculate the end-to-end rate R_2 , the UR has to know r_1 and r_2 . To do that, at step 805, the UR listens the channel, and receives beacon packets from the AP. By using the received beacon packet of the AP, the UR first observes the RSSI value of the signal coming from the AP, and then determines the transmission rate R_1 . Next, the UR determines the rate on the link between the client and itself, R_2 . The RSSI value of the signal coming from the client allows the UR to calculate rate R_2 . Finally, the UR observes all the rates, r_1 , r_2 and R_1 . The end-to-end transmission rate R_2 is calculated by applying equation (1).

[0036] To provide the client to have the maximum throughput, the UR decides whether the client associated with the AP or itself. At step 806, this decision is given by the UR by comparing the rates R_1 and R_2 . In one embodiment of the invention, if the difference between the rates R_1 and R_2 is not too much, the client may not wish to experience frequent association/disassociations. Therefore, in this embodiment of the invention, a threshold based association scheme is employed, where the client association is performed only if the difference between R_1 and R_2 is higher than a pre-defined threshold. If the difference between R_1 and R_2 is higher than the threshold then for the client associating with the AP is more beneficial in terms of the maximum achievable throughput. Hence, at step 807, the UR transmits disassociation frame to the client, and the client disconnects from the UR, and it associates with the AP. Otherwise, the client keeps associating with the UR.

[0037] Fig 6. is a block diagram showing an example of a hardware configuration of the UR. The UR has a CPU, a memory, Medium Access Control (MAC) chip, a Radio Frequency Chip (RF) with antennas. These elements are connected by a bus that is possible for a bidirectional data communication. The CPU reads program from the memory and realizes

various functions of the UR. The memory temporary stores the data, which is required during the execution of the program. The CPU and the memory can be configured as separate or can be configured as one.

[0038] In Fig. 6, wireless communication is realized by MAC and RF chip. At MAC chip, the clients and the AP access to the wireless medium in the pre-defined rules which are defined according to the IEEE 802.11 standard. At RF chip, the data packets are converted to radio waves and are transmitted to the wireless medium via antennas. The invention is implemented at MAC chip via a software program that can be easily deployed at any MAC chip with the capability of IEEE 802.11k standard.

[0039] Different from deploying an UR at homes, another way to mitigate the bad effect of the wireless medium and to extend the coverage of wireless network is using multiple APs to create a wireless mesh network, and to deliver data over this mesh network. However, although the coverage is extended significantly, since the wireless mesh points (MPs) use the same limited wireless medium, the available capacity is shared among all mesh points, which may cause some level of decrease in the end-to-end throughput of a client as in the case of using an UR.

[0040] Although an UR just amplifies and retransmits an incoming signal, a MP can decide more intelligent decision such as routing in which it can change the direction of the communication according to some required constraints. For instance a MP can transmit data over the path which will provide the minimum contention or the maximum throughput. However, a client usually associates with the closet MP since its RSSI is higher than other MPs in the network. Hence, the end-end throughput does not usually taken into account when association decision is given, which causes the same inefficiency problem occurred in the network where UR are used for range extension.

[0041] Fig. 9 shows an example network where mesh points denoted as MPs are connected to the AP wirelessly. Also, the clients may connect the MPs via wireless connections, or they may connect to the AP directly without communication with the MPs. For a downlink scenario, the client receives data from the AP through MPs, where the clients' data first arrives into one of the MP, then that MP transmits the data to the clients. For uplink scenario, the clients wish to transmit data to the AP or gateway. The client may transmit directly to the AP or to a MP. Then, that MP transmits data to the AP wirelessly. For both downlink and uplink scenarios, the end-to-end throughput between the client and the AP should be taken account, and the decision of the client association is given with the knowledge of the end-to-end transmission rate.

[0042] Fig. 10 is a flow chart illustrating a basic method for the invention implemented at the MPs. At step 1001, the current MP with which the client is associated transmits BRqF to the client and the other MPs. If the BRqF is not received by any of MPs or the client, the MP keeps transmitting BRqF until all other MPs and the client accept it.

[0043] At step 1004, the client collects beacon packets that it receives from other MPs and the AP, and observes the corresponding RSSI values. Then, the client prepares 802.11k Beacon Request Reports which contains the information about the received beacon packets with the corresponding RSSI values, and sends it to the current MP.

[0044] At step 1005, the other MPs also collect beacon packets that they receive from the AP, and report it to the current MP.

[0044] At step 1006, the MP determines all possible end-to-end throughput on each link between the AP and the client by using the gathered transmission rates at step 1004 and step 1005.

[0045] At step 1007, the current MP determines the best link with the maximum end-to-end throughput is observed. If the current MP involves with the best link, then the client keeps connecting to the current MP.

[0046] The best link may not always involve with the current MP. In this case, the client shall associate with the MP that involves with the best link. To do that first, the current MP determines the MP which involves with the best link. In the next phase, the current MP needs to inform the client about the new MP with the maximum end-to-end throughput. In one embodiment of the invention, 802.11v packets are used to inform client devices in a standard-compliant manner. Other standard-compliant methods or proprietary ones may be used to convey the same information. 802.11v provides the wireless resource management enhancements to 802.11. While 802.11k provides the frames to gather useful network information by measuring, 802.11v enables the ability of configuring the clients. IEEE 802.11v standard includes the following special frame:

- Association Request Frame (ARF): In an ARF, an AP specifies one or more MAC addresses of the candidates APs with which a client may associate.

[0047] If the link with the maximum end-to-end throughput contains a different MP from the current MP, the current MP sends ARF to the client by indicating the MP which is on the link with the maximum end-to-end throughput.

[0048] After the client receiving ARF, it disassociates with the current MP, and associates with the MP indicated within the ARF.

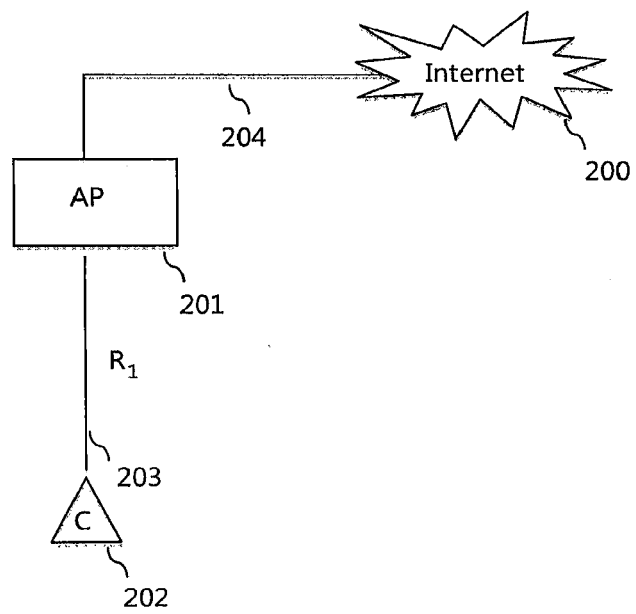


Figure 2

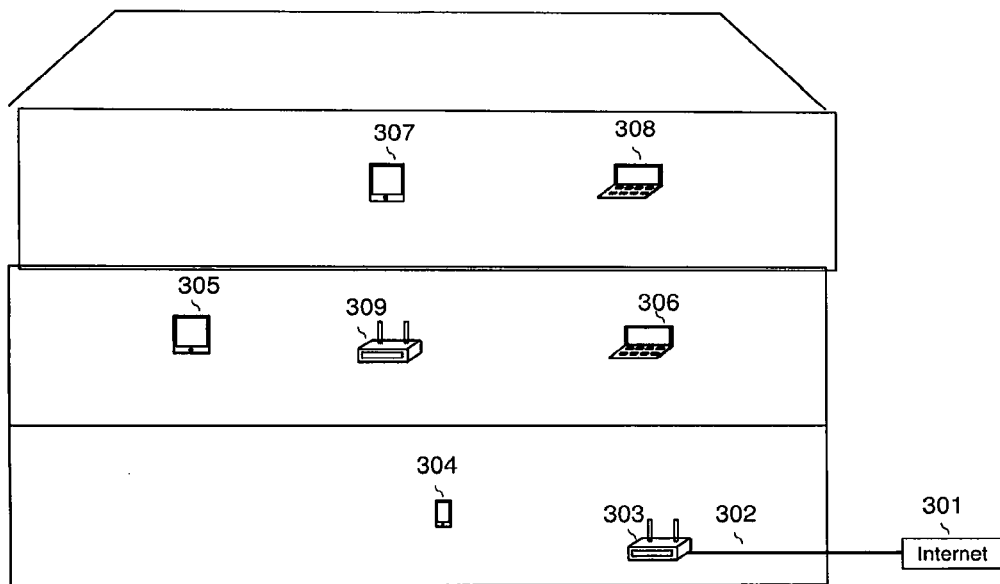


Figure 3

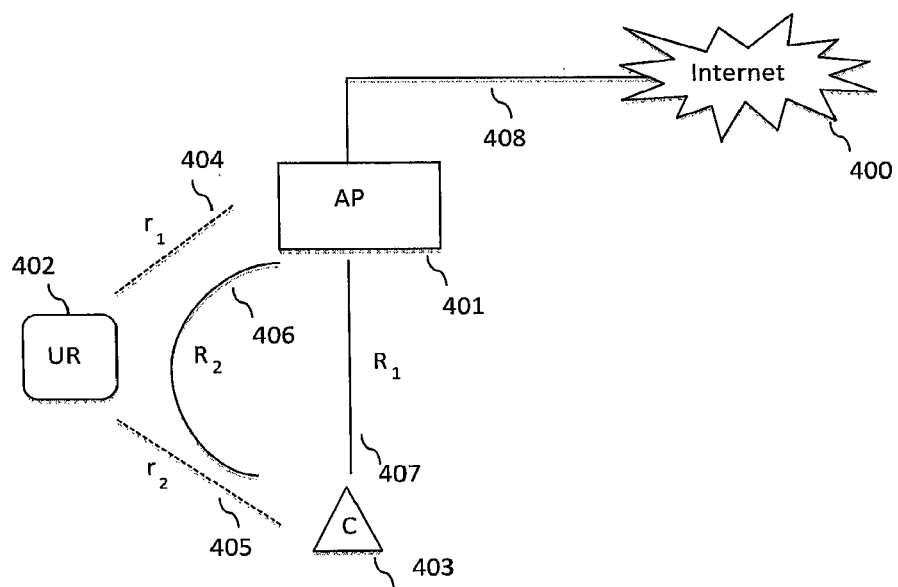


Figure 4

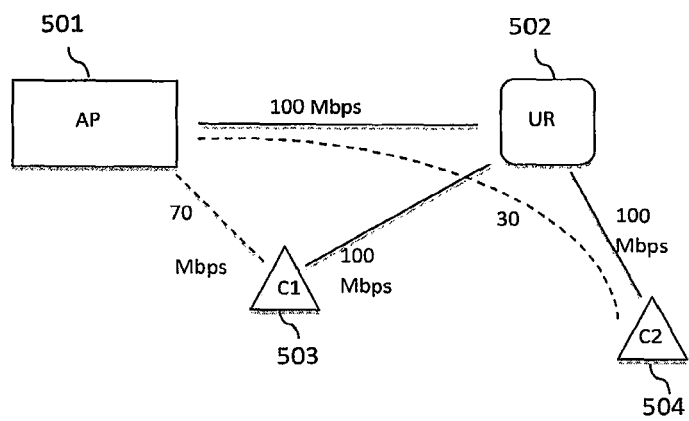


Figure 5

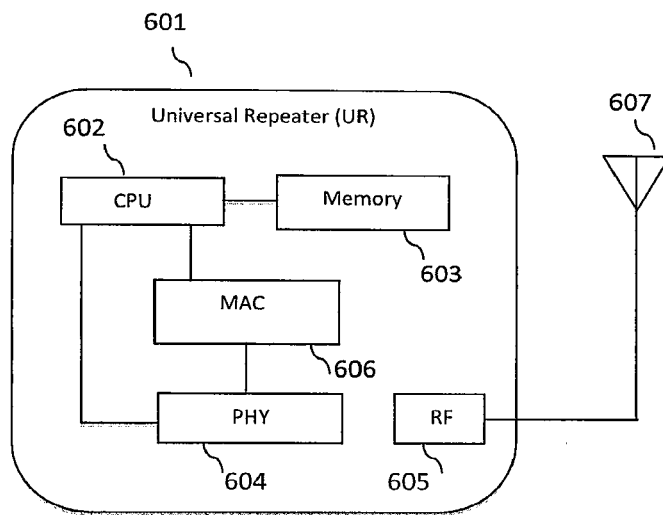


Figure 6

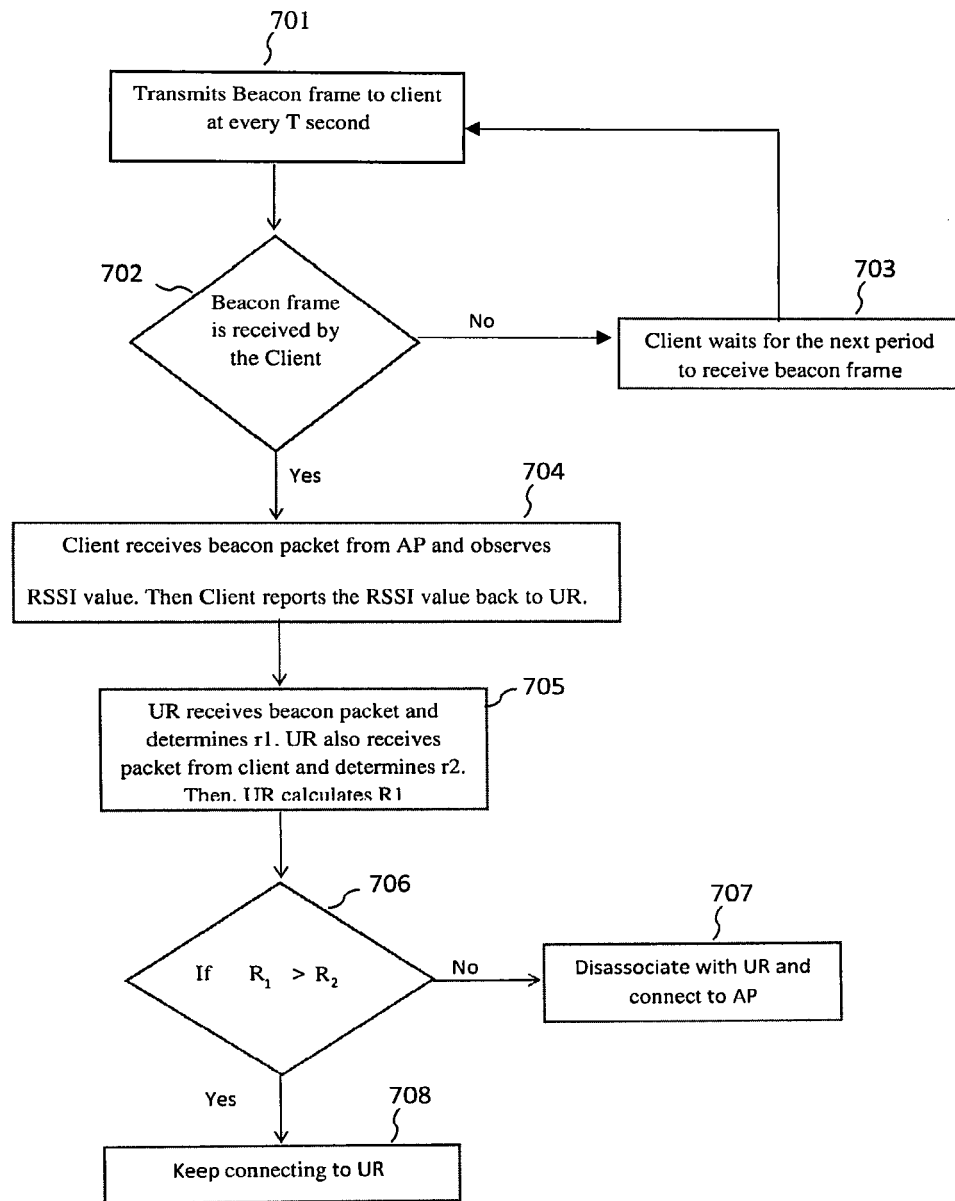


Figure 7

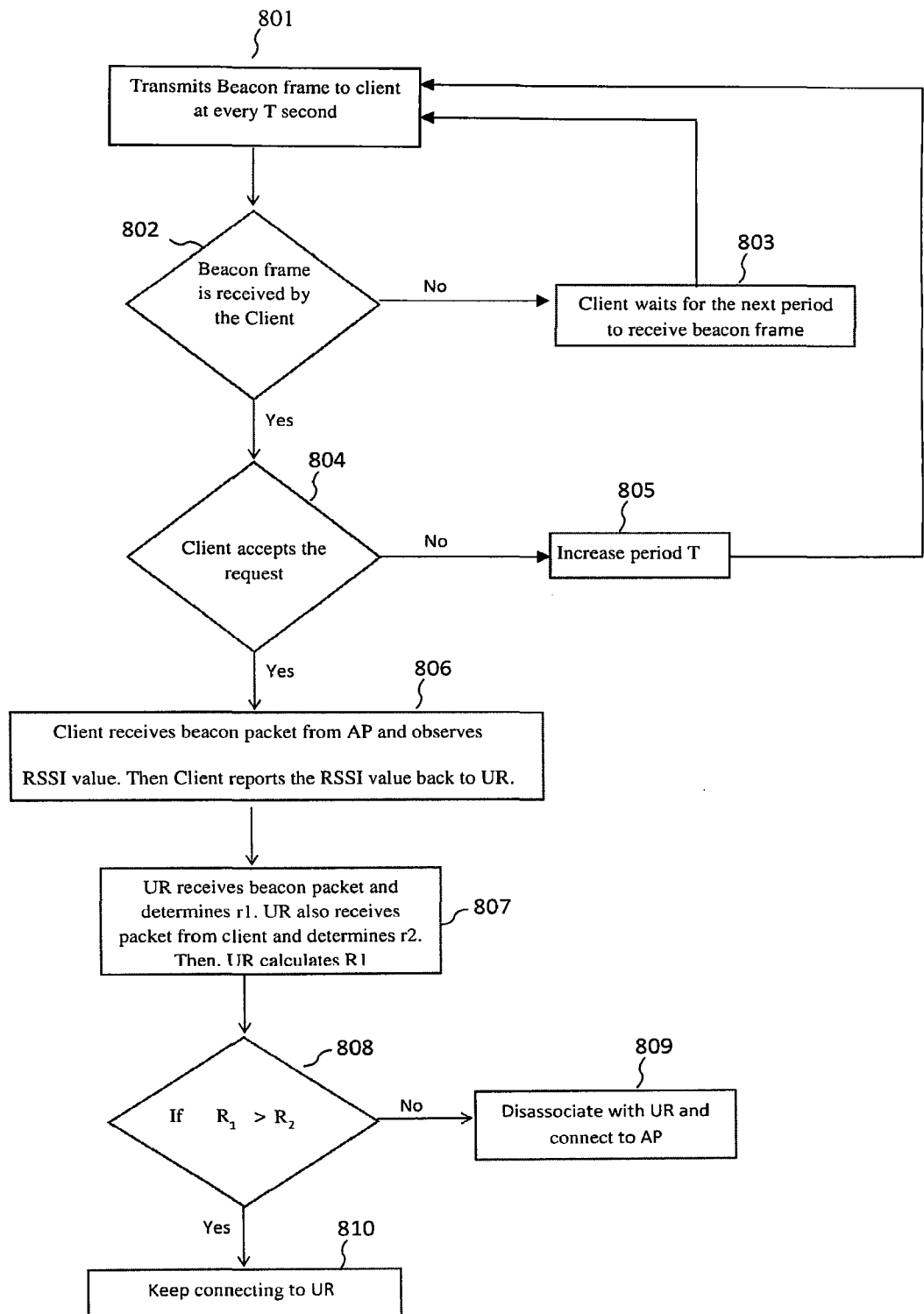


Figure 8

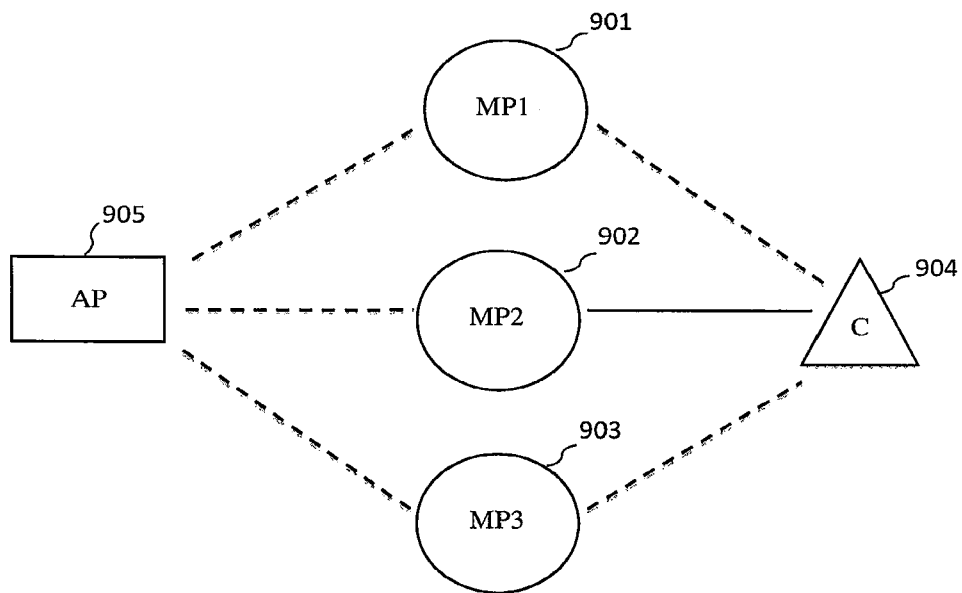


Figure 9

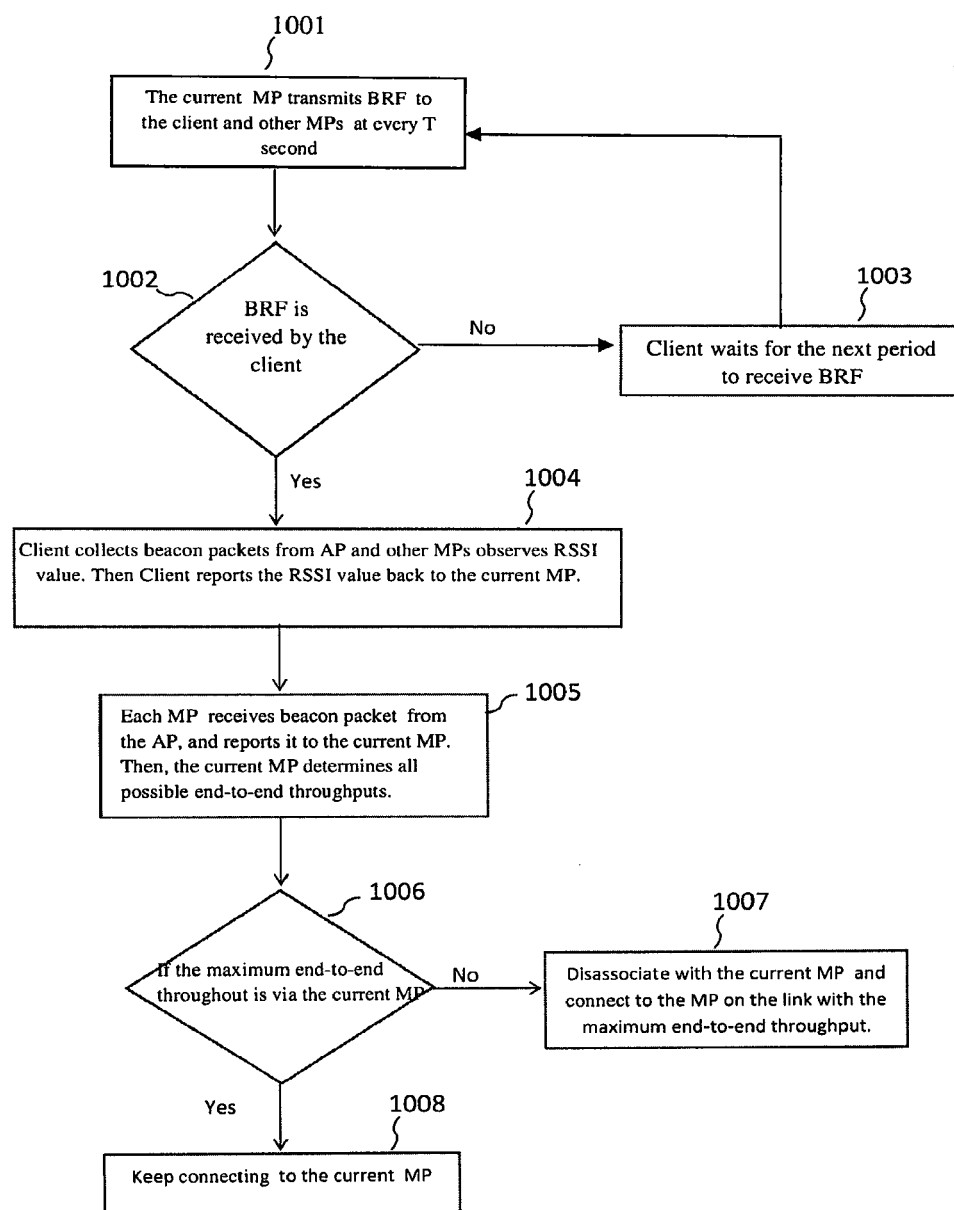


Figure 10