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(54) **Title**: METHOD FOR OPERATING A WI-FI STATION AND WI-FI STATION

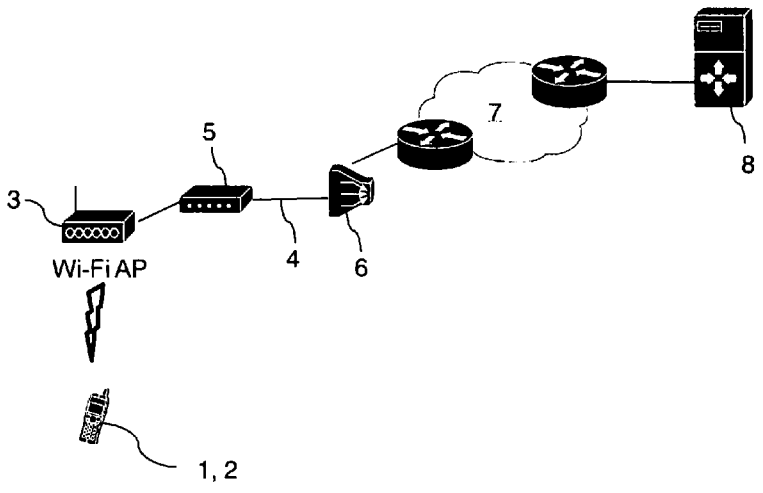

Fig. 1

(57) **Abstract**: A method for operating a Wi-Fi station being associated to a Wi-Fi access point (2), wherein said Wi-Fi station (1) is configured to be operable in different power management modes, including at least an active mode with said Wi-Fi station (1) being in an awake state, in which said Wi-Fi station (1) is fully powered and is able to receive frames at any time, and a power save mode with said Wi-Fi station (1) being in a doze state, in which said Wi-Fi station (1) is at least partly powered down and polls said Wi-Fi access point (2) in predefined time lags - trigger intervals - for pending frames, wherein said Wi-Fi station (1) is enabled to perform transitions between said different power management modes, is characterized in that the power management mode employed by said Wi-Fi station (1) is selected depending on the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point (3) and/or the amount of traffic transmitted by said Wi-Fi station (1). Furthermore, a corresponding Wi-Fi station is disclosed.

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METHOD FOR OPERATING A WI-FI STATION AND WI-FI STATION

The present invention relates to a method for operating a Wi-Fi station being associated to a Wi-Fi Access Point, wherein said Wi-Fi station is configured to be operable in different power management modes, including at least an active mode with said Wi-Fi station being in an awake state, in which said Wi-Fi station is fully powered and is able to receive frames at any time, and a power save mode with said Wi-Fi station being in a doze state, in which said Wi-Fi station is at least partly powered down and polls said Wi-Fi Access Point in predefined time lags – trigger intervals – for pending frames, wherein said Wi-Fi station is enabled to perform transitions between said different power management modes. Furthermore, the present invention relates to a corresponding Wi-Fi station.

Wi-Fi networks are nowadays widely deployed in homes, enterprises and public spaces to offer Internet connectivity. In addition, the Wi-Fi technology is becoming pervasive among mobile computing devices, with this trend expected to become even more significant in the near future. Within this scenario, it is important to notice that mobile computing devices, like smartphones or tablets, are battery limited, and it is therefore of capital importance to deploy technologies that allow these devices to access the Internet in an energy efficient manner. Fig. 1 represents a common Internet access scenario using Wi-Fi. Throughout this patent application the device that is seeking for a Wi-Fi connection will be generally referred to as Wi-Fi station.

In order to address the energy efficiency problem on the side of the Wi-Fi stations, the Wi-Fi technology defines several power saving protocols, which are specified in the *IEEE Standard for Information Technology-Telecommunications and Information Exchange Between Systems-Local and Metropolitan Area Networks-Specific Requirements - Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE Std 802.11-2007.* The behavior of these power saving protocols can be summarized in the following way. A Wi-Fi station enters a power save mode and switches its Wi-Fi radio off in order to save energy. Thereafter, the Access Point (AP) buffers any data received for the

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sleeping station, and notifies the station about its pending data once every 100 ms using the Beacon frame. The Wi-Fi station wakes up to receive the Beacon frame, and if there is pending data buffered at the AP, it triggers the AP for the delivery of this data.

As can be inferred from the previous description, using a Wi-Fi power saving protocol affects the performance of the communications flows running in the Wi-Fi station. The reason is that packets for the Wi-Fi station arriving at the Wi-Fi AP are delayed until the next Beacon transmission, and this delay degrades the performance of ongoing communications. Hence, given the inherent trade-off between application performance and energy efficiency created by Wi-Fi power saving protocols, there are two common strategies deployed in the state of the art:

- Active Mode: In this mode, the Wi-Fi station operates in power save mode, but whenever some traffic is detected it switches to Active Mode until the communication finishes. This strategy provides a good application performance but may result in extra energy waste while the communication is ongoing.

- Wi-Fi PSM: In this mode, the Wi-Fi station operates all the time in power save mode. This strategy is energy efficient, but may significantly degrade the performance of the applications running over the Wi-Fi station.

Other solutions have been proposed in the literature but they are not widely deployed in the context of Fig. 1, because of a variety of reasons. For instance, G. Anastasi et al.: "*802.11 power saving mode for mobile computing in Wi-Fi hotspots: limitations, enhancements and open issues*", Wireless Networks 14, 6 (Dec. 2008), and E. Tan et al.: "*PSMthrottling: Minimizing Energy Consumption for Bulk Data Communications in WLANs*", Proceedings of the IEEE International Conference on Network Protocols, Oct. 16-19, 2007, Beijing, China, ICNP 2007, pp.123-132 describe PSM schemes which require complex cross-layer modifications that hinder deployment. The approach described in R.Krashinsky and H.Balakrishnan: "*Minimizing energy for wireless web access with bounded slowdown*", Proceedings of the 8th Annual International Conference on Mobile Computing and Networking (MOBICOM), September 2002 targets only Web traffic

and may be significantly less energy efficient than Wi-Fi PSM. Finally, the technique applied in D. Camps Mur et al.: "*An Adaptive Solution for Wireless LAN Distributed Power Saving Modes*", Elsevier Computer Networks Journal (CN), Volume 53, Issue 18, December 2009 is disadvantageous in that it targets only real-time traffic like Voice or Video.

It is therefore an object of the present invention to improve and further develop a method for operating a Wi-Fi station and a Wi-Fi station of the initially described type in such a way that, by employing mechanisms that are readily to implement, the described performance/energy trade off in the general context of Data applications, e.g. Web and File Transfers, is resolved in an efficient and reliable fashion, i.e. that efficient power saving is achieved for the Wi-Fi station without significantly degrading the performance and the experienced QoS.

In accordance with the invention, the aforementioned object is accomplished by a method comprising the features of claim 1. According to this claim, such a method is characterized in that the power management mode employed by said Wi-Fi station is selected depending on the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point and/or the amount of traffic transmitted by said Wi-Fi station.

Furthermore, the aforementioned object is accomplished by a Wi-Fi station comprising the features of claim 11. According to this claim, such a Wi-Fi station is characterized in that the Wi-Fi station selects its employed power management mode depending on the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point and/or the amount of traffic transmitted by said Wi-Fi station.

According to the invention it has been recognized that the performance/energy trade off discussed above can be resolved by an adaptive solution, in which the operational mode of the Wi-Fi station is dynamically selected according to specific conditions. More specifically, in the method according to the present invention the decision of what power saving protocol is actually employed (and which trigger interval is used in power save mode) is based on either the bottleneck bandwidth

experienced by traffic flowing through the Wi-Fi Access Point or the total amount of traffic transmitted by the Wi-Fi station, or on a combination of both parameters. It is important to note that in the scenario depicted in Fig. 1 typically the bottleneck of the bandwidth will be located in the access technology connecting the Access Point to the Internet, e.g. in a DSL link. As a result, in contrast to current solutions in the state of the art, which incur a penalty either in terms of application performance or in terms of energy efficiency, the present invention delivers a good trade-off between performance of the applications running in the Wi-Fi station and energy efficiency, i.e. battery life of the Wi-Fi station.

A further advantage of the present invention is to be seen in the fact that the method can be easily implemented without requiring any modifications to existent standards. Therefore, the method according to the present invention can be immediately used in any existent Wi-Fi network and can be implemented just with a software/firmware upgrade to existent devices. In addition, the proposed invention can be deployed/implemented entirely at Layer 2 since all the required information can be obtained at L2. Hence, it is easy to re-use it in any device with a Wi-Fi interface.

According to a preferred embodiment it may be provided that the bottleneck bandwidth experienced by traffic flowing through the Wi-Fi Access Point is discovered by running an end-to-end bandwidth estimation technique in the Wi-Fi station, which is associated to a Wi-Fi Access Point that provides Internet connectivity through a technology like e.g. DSL. The estimation may be carried out by the Wi-Fi station taking into consideration the communication flows running in the Wi-Fi station.

In a specific embodiment the end-to-end bandwidth estimation scheme may be based on the observation of the interarrival times between consecutive frames received from the Access Point at the Wi-Fi station. More specifically, the end-to-end bandwidth estimation scheme disclosed in S. Kandula et al.: "FatVAP: Aggregating AP Backhaul Capacity to Maximize Throughput", 5th USENIX Symposium on Networked Systems Design and Implementation, April 2008, which is specific to Wi-Fi, may be employed. Details of the scheme are to be found in

section 3.1.2 of the mentioned document, the disclosure of which is incorporated herein by way of reference.

Alternatively or additionally, the end-to-end bandwidth estimation scheme may be based on the pathload software developed by C. Dovrolis (see for reference http://www.pathrate.org). The software can be run the Wi-Fi station in order to obtain an estimate on the available end-to-end bandwidth. Details of the underlying algorithms can be inferred from sections 3 and 4 of the document M. Jain and C. Dovrolis: "End-to-end available bandwidth: measurement methodology, dynamics, and relation with TCP throughput", in Journal IEEE/ACM Transactions on Networking (TON), Volume 11, Issue 4, August 2003, which is incorporated herein by way of reference.

As will be apparent to a person skilled in the pertaining art, the deployment of other end-to-end bandwidth estimation schemes can also be envisioned where suitably applicable.

Similarly to the bottleneck bandwidth estimation it may be provided that the amount of traffic transmitted by the Wi-Fi station is determined by estimating the amount of traffic offered by applications running in the Wi-Fi station.

With respect to efficient performance it may be provided that the Wi-Fi station operates in active mode in case the bottleneck bandwidth and the amount of traffic transmitted by the Wi-Fi station exceed predefined thresholds. In such case, since relatively high data rates can be transported over the connection between the Wi-Fi Access Point and the Internet, which might be a fast DSL line with e.g. 16Mbps/1Mbps DSL technology, it is profitable (with respect to the wireless throughput between the Wi-Fi Access Point and the Wi-Fi station) to keep the Wi-Fi station continuously in an awake state, such that it is permanently enabled to receive (and transmit) frames.

On the other hand, in case the bottleneck bandwidth and the amount of traffic transmitted by said Wi-Fi station fall below predefined thresholds it may be provided that the Wi-Fi station performs a transition to the power save mode.

With respect to increasing efficiency even more by way of further dynamic adaptations, in case the Wi-Fi station operates in power save mode it may be provided that the trigger interval (or polling interval) of the power save mode, i.e. how often the Wi-Fi station polls the Wi-Fi Access Point for pending data, is adjusted depending on the bottleneck bandwidth and/or the amount of traffic transmitted by the Wi-Fi station. For instance, a continuous adaptation could be realized in the following fashion. In case the bottleneck bandwidth increases and/or the amount of traffic transmitted by said Wi-Fi station exceeds a predefined threshold the trigger interval may be decreased. On the other hand, in case the bottleneck bandwidth decreases and/or the amount of traffic transmitted by the Wi-Fi station falls below a predefined threshold the trigger interval may be increased. In order to avoid hysteresis effects a scheme could be implemented according to which trigger interval adaptation are performed only in case the change (increase or decrease) of the bottleneck bandwidth and/or the amount of traffic transmitted by the Wi-Fi station exceeds a predefined magnitude.

Instead of a continuous adaptation of the trigger interval, a discrete adaptation in two or more distinct steps may be realized. For instance, if the bottleneck bandwidth is high (e.g. exceeding a predefined threshold) and the application running in the Wi-Fi station offer enough traffic (e.g. also exceeding a predefined threshold), the Wi-Fi station may operate in power save mode using a small trigger interval of a certain length. If the bottleneck bandwidth is low (e.g. below a predefined threshold) or the applications running in the Wi-Fi station do not offer enough traffic (e.g. also below a predefined threshold), the Wi-Fi station may switch its operational status to a power save mode with big trigger intervals of a certain length. Generally, in this context it is important to note that where the bottleneck bandwidth being "high" or "low" has to be understood as compared to the Wi-Fi bandwidth. For instance, a DSL bandwidth of 1 Mbps with a Wi-Fi AP at 54 Mbps that provides an effective bandwidth of ~25 Mbps is low. On the other hand, a VDSL (Very High Speed Digital Subscriber Line) or FTTH (Fiber To The Home) bandwidth of 50 Mbps or 100 Mbps is high.

There are several ways how to design and further develop the teaching of the

present invention in an advantageous way. To this end it is to be referred to the patent claims subordinate to patent claims 1 on the one hand and to the following explanation of preferred embodiments of the invention by way of example, illustrated by the drawing on the other hand. In connection with the explanation of the preferred embodiments of the invention by the aid of the drawing, generally preferred embodiments and further developments of the teaching will we explained. In the drawing

Fig. 1 is a schematic view of the general scenario for applying a method according to an embodiment of the present invention,

Fig. 2 is a diagram illustrating the performance characteristics of active mode operation versus power save mode operation according to prior art,

Fig. 3 is a diagram illustrating the performance characteristics of an operational mode according to an embodiment of the present invention,

Fig. 4 is a diagram illustrating the effects of selecting the trigger interval based on the bottleneck bandwidth according to an embodiment of the present invention, and

Fig. 5 is a diagram illustrating the effects of switching the Wi-Fi station to active mode based on the bottleneck bandwidth according to another embodiment of the present invention.

Referring to Fig. 1, a Wi-Fi station 1, which is assumed to be e.g. a smartphone 2, has established a Wi-Fi connection to a Wi-Fi access point (Wi-Fi AP) 3. The Wi-Fi AP 3 is connected via a DSL line 4, e.g. by using a modem 5, to a DSLAM (Digital Subscriber Line Access Multiplexer) 6, which is the network-side counterpart of the modem 5 employed on the side of the user. The DSLAM 6 controls the DSL traffic between the Wi-Fi AP 3 and the Internet 7, for instance the data traffic exchanged between the Wi-Fi AP 3 and a File Server 8.

Fig. 2 is a diagram illustrating the performance characteristics of active mode operation versus power save mode operation according to prior art. More specifically, the diagram depicts the results of experiments carried out in the context of a basic architecture as described in connection with Fig. 1. Different deployment scenarios have been realized, which are a) a slow DSL line 4 with 1 Mbps/128 Kbps DSL technology, b) a fast DSL line 4 with 16 Mbps/1 Mbps DSL technology, as well as c) a scenario in which the bandwidth bottleneck is not in the access link, but in the Wi-Fi network, i.e. between the Wi-Fi station 1 and the Wi-Fi AP 3. This could be the case of an FTTH deployment.

The experiment consists in having the Wi-Fi station 1 in Fig. 1 retrieve a 50 MB file from the File server 8 in Fig. 1, while varying the amount of buffering in the bottleneck node, i.e. in the DSLAM 6 in scenarios a) and b) and in the Wi-Fi AP 3 in case of scenario c). For all three scenarios the experiment was repeated with the Wi-Fi station 1 using either Active Mode or Wi-Fi PSM. The left column in Fig. 2 depicts the throughput (in Mbps) obtained in the File transfer and the right column in Fig. 2 the energy (in Joules per MB) spent by the Wi-Fi station 1 to perform such transfer.

As can be clearly obtained from Fig. 2, when the bandwidth bottleneck is located in the (DSL) access line between the Wi-Fi AP 3 and the Internet 7 and the bandwidth in the bottleneck is comparatively small – scenario a) – the Active Mode strategy delivers the same throughput as the Wi-Fi PSM one, but with a much higher energy cost. In case that the bandwidth bottleneck is still located in the (DSL) access line between the Wi-Fi AP 3 and the Internet 7, but the bandwidth in the bottleneck being comparatively high – scenario b) – the Active Mode strategy delivers a significantly higher throughput than the Wi-Fi PSM one, but again with higher energy costs, the difference in energy cost being more apparent in case of a comparatively fast Wi-Fi connection.

On the other end of the spectrum, when the bandwidth of the bottleneck is located in the Wi-Fi connection – scenario c) –, the Wi-Fi PSM strategy heavily degrades throughput, and it can even result in higher energy costs. The reason for the observed results is that the extra delay introduced by Wi-Fi PSM does not have a

big impact when the bottleneck bandwidth is small, but can severely degrade performance when the bottleneck bandwidth grows. In addition, it is important to note that in a scenario like the one depicted in Fig. 1, the bottleneck is typically located in the access technology connecting the Wi-Fi AP 3 to the Internet 7 (e.g. the DSL link 4 in Fig. 1).

Taking the above results into consideration the present invention proposes an adaptive solution that adjusts and/or configures the used power saving protocol depending on the bottleneck bandwidth experienced by the communications running in the Wi-Fi station 1. In a specific embodiment of the present invention a method that runs in the Wi-Fi station 1 and that consists of the following building blocks may be realized:

- The Wi-Fi station 1 estimates the bottleneck bandwidth experienced by the communication flows running in the Wi-Fi station 1.
- The Wi-Fi station 1 estimates the amount of traffic or load offered by the applications running in the Wi-Fi station 1.
- Depending on the previous two estimates the Wi-Fi station 1 decides whether to operate in power save mode or in Active Mode and, in case of power save mode operation, it controls the trigger interval in the power saving protocol (i.e. how often the Wi-Fi station 1 polls the Wi-Fi AP 3 for new data), in the following way:
    - If the estimated bottleneck bandwidth is high and the applications running in the Wi-Fi station 1 offer enough traffic, the Wi-Fi station 1 operates in power save mode using small trigger intervals, or operates in Active Mode.
    - If the estimated bottleneck bandwidth is low or the applications running in the Wi-Fi station 1 do not offer enough traffic, the Wi-Fi station 1 operates in power save mode using big trigger intervals.

It is to be noted that the terms “small” and “big” with respect to the trigger intervals are intended to indicate a tendency only, whereas the specific values have to be determined/adjusted during operation depending on the existing situation and the prevailing conditions.

Fig. 3 depicts how the described embodiment of the method according to the present invention performs in the experiment described in connection with Fig. 2 compared to the two strategies typically deployed in the market. It is easy to see how the proposed method delivers a very good trade-off between performance and energy efficiency across all considered scenarios a), b) and c), with a throughput almost equivalent to the one of the Active Mode strategy and energy efficiency even better than the one of the Wi-Fi PSM strategy.

In addition, Fig. 4 depicts a sample of the operation of an embodiment of the method according to the present invention in the fast DSL scenario (16Mbps/1Mbps), i.e. scenario b). As can be obtained from Fig. 4, the Wi-Fi station 1 estimates the bottleneck bandwidth (16Mbps in the right axis, indicated by the line denoted "peak rate"). Based thereupon, the Wi-Fi station 1 adjusts the trigger interval in the power saving protocol (indicated by the line denoted "interval"), by reducing the trigger interval from 100 ms (as employed by the standard Wi-Fi PSM) to around 40ms (indicated in the left axis). By taking this measure the Wi-Fi station 1 achieves the required performance, which is a fraction of the bottleneck bandwidth indicated by the line denoted "$ratio_{min}$*peak_rate". The achieved performance is the throughput experienced by the file transfer which is indicated by the line denoted "instant_thr". To summarize, the example of Fig. 4 clearly illustrates how the method according to the present invention, by selecting in the illustrated case a trigger interval around 40 ms, being smaller than the one used by Wi-Fi PSM (100 ms), can significantly improve the File transfer throughput while at the same time being highly energy efficient.

Fig. 5 depicts another example, corresponding to scenario c), where the bottleneck bandwidth is in the Wi-Fi connection between the Wi-Fi station 1 and the Wi-Fi AP 3 with a relatively high value between 30 and 40 Mbps. In accordance with an embodiment of the present invention the Wi-Fi station 1 takes this bandwidth bottleneck situation into consideration and decides to operate in Active Mode (as indicated by the lines being denoted by "interval" being equal to zero between ~92 seconds and ~100 seconds in Fig. 5), which in this case is energy efficient and yields high throughput. In the diagram of Fig. 5 the switch

from Power Save Mode (with a trigger interval of around 20 ms) to Active Mode takes place at a value of approx. 92 sec on the time axis. As a result of the transition the throughput (indicated by the line denoted "instant_thr") increases to reach a value that basically corresponds to the bottleneck bandwidth of approx. 40 Mbps.

Many modifications and other embodiments of the invention set forth herein will come to mind the one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. Method for operating a Wi-Fi station being associated to a Wi-Fi access point (2), wherein said Wi-Fi station (1) is configured to be operable in different power management modes, including at least

an active mode with said Wi-Fi station (1) being in an awake state, in which said Wi-Fi station (1) is fully powered and is able to receive frames at any time, and

a power save mode with said Wi-Fi station (1) being in a doze state, in which said Wi-Fi station (1) is at least partly powered down and polls said Wi-Fi access point (2) in predefined time lags – trigger intervals – for pending frames,

wherein said Wi-Fi station (1) is enabled to perform transitions between said different power management modes,

characterized in that the power management mode employed by said Wi-Fi station (1) is selected depending on the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point (3) and/or the amount of traffic transmitted by said Wi-Fi station (1).

2. Method according to claim 1, wherein the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point (3) is discovered by running an end-to-end bandwidth estimation scheme in said Wi-Fi station (1).

3. Method according to claim 2, wherein said end-to-end bandwidth estimation scheme is based on the observation of the interarrival times between consecutive frames at said Wi-Fi station (1).

4. Method according to claim 2 or 3, wherein said end-to-end bandwidth estimation scheme is based on pathload calculations.

5. Method according to any of claims 1 to 4, wherein the amount of traffic transmitted by said Wi-Fi station (1) is determined by estimating the amount of traffic offered by applications running in said Wi-Fi station (1).

6. Method according to any of claims 1 to 5, wherein said Wi-Fi station (1)

operates in active mode in case the bottleneck bandwidth and the amount of traffic transmitted by said Wi-Fi station (1) exceed predefined thresholds.

7. Method according to any of claims 1 to 6, wherein said Wi-Fi station (1) operates in power save mode in case the bottleneck bandwidth and the amount of traffic transmitted by said Wi-Fi station (1) fall below predefined thresholds.

8. Method according to any of claims 1 to 7, wherein said trigger interval, in case said Wi-Fi station (1) operates in power save mode, is adjusted depending on the bottleneck bandwidth and/or the amount of traffic transmitted by said Wi-Fi station (1).

9. Method according to any of claims 1 to 8, wherein said trigger interval is decreased in case the bottleneck bandwidth increases and/or the amount of traffic transmitted by said Wi-Fi station (1) exceeds a predefined threshold.

10. Method according to any of claims 1 to 9, wherein said trigger interval is increased in case the bottleneck bandwidth decreases and/or the amount of traffic transmitted by said Wi-Fi station (1) falls below a predefined threshold.

11. Wi-Fi station, being associated to a Wi-Fi access point (2) and being configured to be operable in different power management modes, including at least

an active mode with said Wi-Fi station (1) being in an awake state, in which said Wi-Fi station (1) is fully powered and is able to receive frames at any time, and

a power save mode with said Wi-Fi station (1) being in a doze state, in which said Wi-Fi station (1) is at least partly powered down and polls said Wi-Fi Access Point (2) in predefined time lags – trigger intervals – for pending frames,

wherein said Wi-Fi station (1) is enabled to perform transitions between said different power management modes,

characterized in that the Wi-Fi station (1) selects its employed power management mode depending on the bottleneck bandwidth experienced by traffic flowing through said Wi-Fi Access Point (3) and/or the amount of traffic

transmitted by said Wi-Fi station (1).

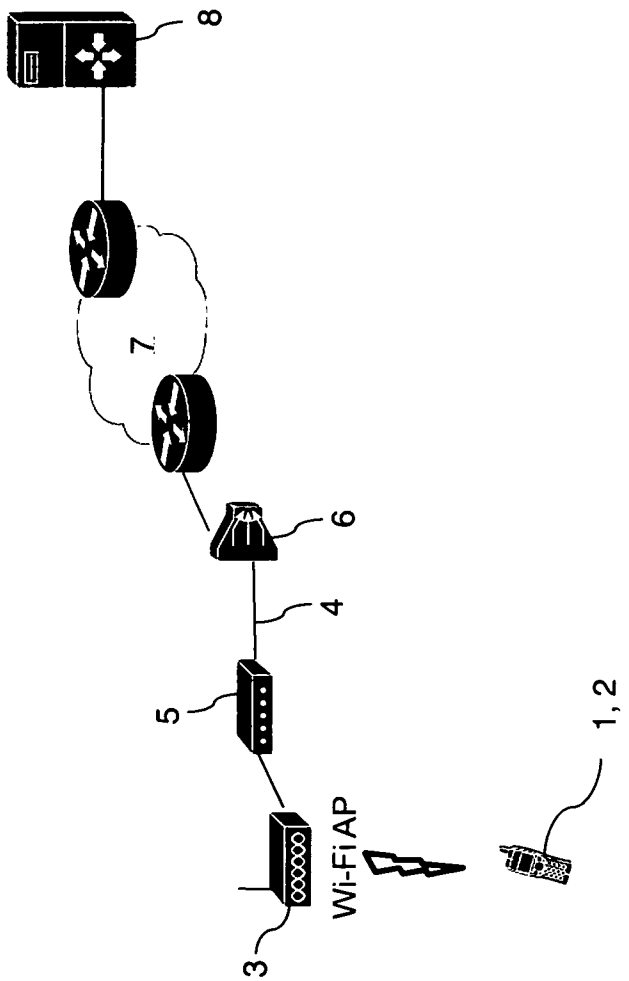


Fig. 1

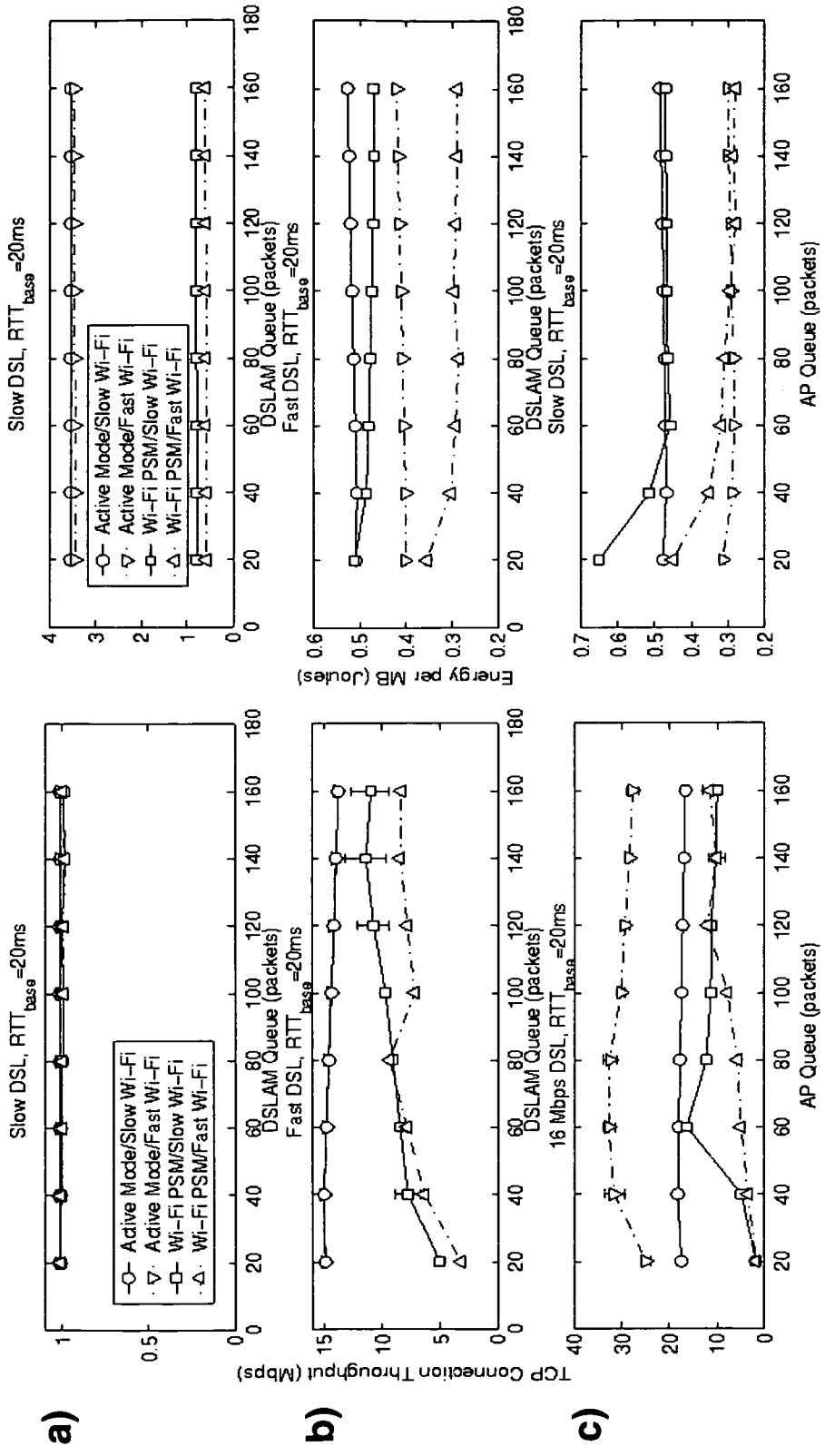

a)
b)
c)
Slow DSL, RTT base =20ms
Fast DSL, RTT base =20ms
16 Mbps DSL, RTT base =20ms
TCP Connection Throughput (Mbps)
Energy per MB (Joules)
DSLAM Queue (packets)
AP Queue (packets)
Active Mode/Slow Wi-Fi
Active Mode/Fast Wi-Fi
Wi-Fi PSM/Slow Wi-Fi
Wi-Fi PSM/Fast Wi-Fi

Fig. 2

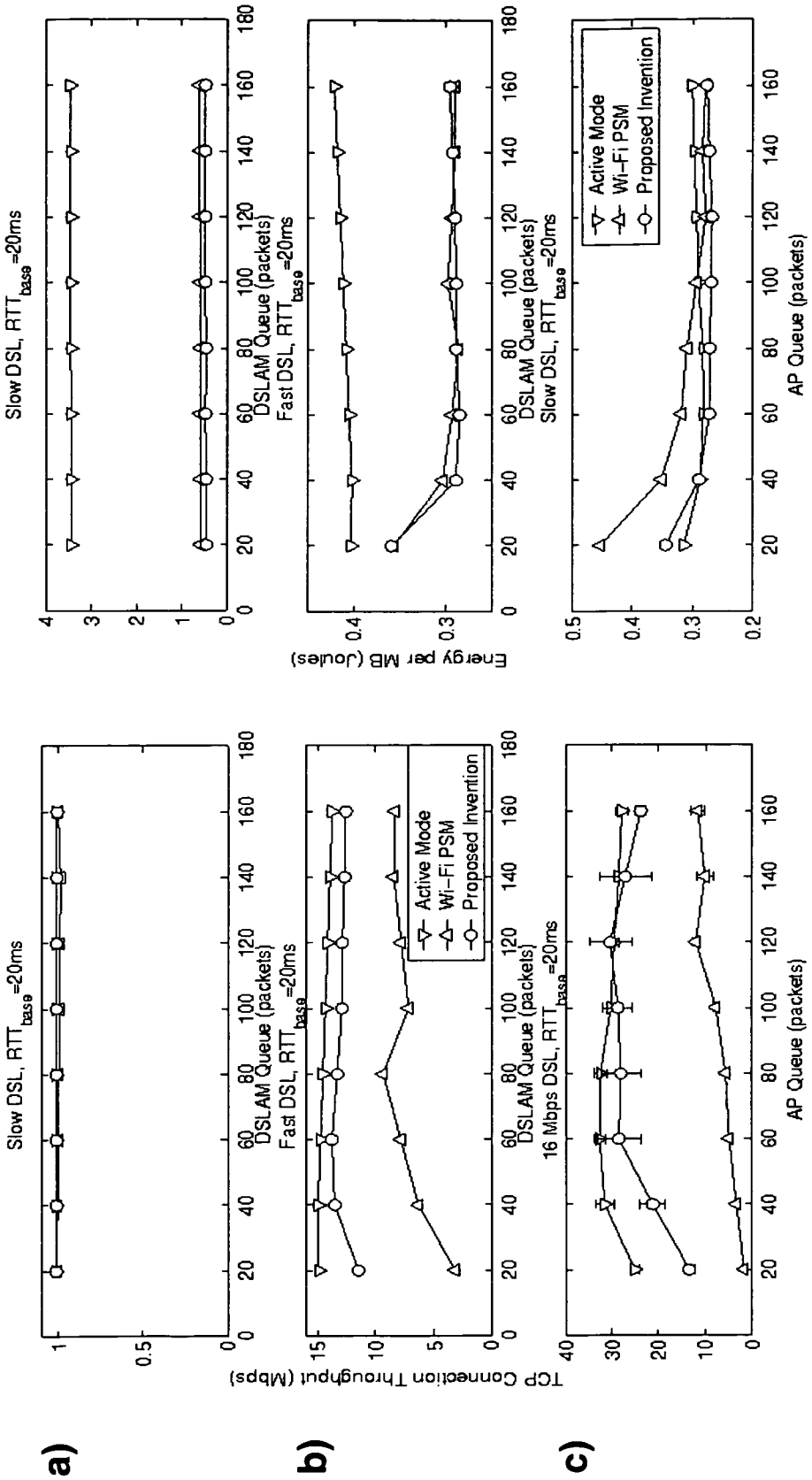
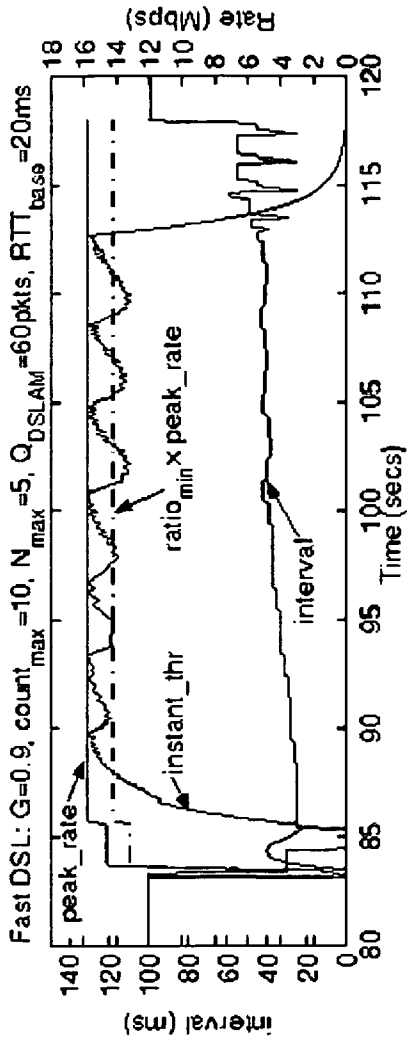

a)
b)
c)
Slow DSL, RTT$_{base}$=20ms
Fast DSL, RTT$_{base}$=20ms
16 Mbps DSL, RTT$_{base}$=20ms
DSLAM Queue (packets)
AP Queue (packets)
TCP Connection Throughput (Mbps)
Energy per MB (Joules)
Active Mode
Wi-Fi PSM
Proposed Invention

Fig. 3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peak_rate
instant_thr
ratio_min x peak_rate
interval
interval (ms)
Rate (Mbps)
Time (secs)
140
120
100
80
60
40
20
0
18
16
14
12
10
8
6
4
2
0
80
85
90
95
100
105
110
115
120

Fig. 4

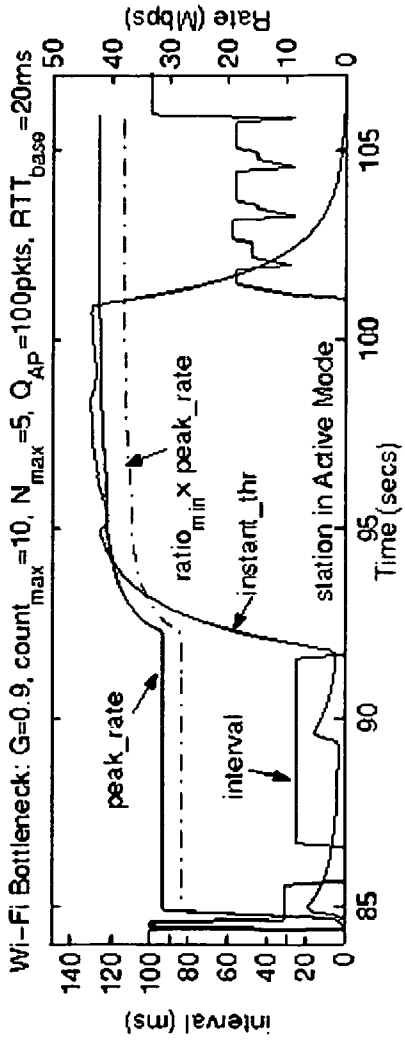
Wi-Fi Bottleneck: G=0.9, count_max=10, N_max=5, Q_AP=100pkts, RTT_base=20ms
interval (ms)
Rate (Mbps)
Time (secs)
peak_rate
interval
ratio_min x peak_rate
instant_thr
station in Active Mode
0
20
40
60
80
100
120
140
0
10
20
30
40
50
85
90
95
100
105

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/004428

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W52/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/310618 A1 (CARTER TRENT [US]) 17 December 2009 (2009-12-17) cited in the application abstract paragraphs [0005], [0018], [0023] paragraph [0035] - paragraph [0037] figures 2, 3	1-11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2012	17/01/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rosenauer, Hubert

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ANASTASI G ET AL: "802.11 power-saving mode for mobile computing in Wi-Fi hotspots: Limitations, enhancements and open issues", WIRELESS NETWORKS ; THE JOURNAL OF MOBILE COMMUNICATION, COMPUTATION AND INFORMATION, KLUWER ACADEMIC PUBLISHERS, DO, vol. 14, no. 6, 17 January 2007 (2007-01-17), pages 745-768, XP019650447, ISSN: 1572-8196 abstract page 745, right-hand column, paragraph 1 - page 746, right-hand column, paragraph 1 page 749, right-hand column, paragraph 3.2 - page 750, left-hand column, paragraph 3.3 page 757, left-hand column, paragraph 6.2.2 - page 757, right-hand column, paragraph 6.2.2 page 760, left-hand column, paragraph 6.2.3 - page 760, right-hand column, paragraph 6.2.3 page 763, right-hand column, paragraph 7.2 - page 764, left-hand column, paragraph 7.2 figure 1	1-11

A	US 2007/037609 A1 (ZHANG TAO [US] ET AL) 15 February 2007 (2007-02-15) abstract paragraphs [0002], [0011], [0021], [0030] figures 2, 4	1,11

A	US 2010/002612 A1 (HSU CHUNG-HSIEN [TW] ET AL) 7 January 2010 (2010-01-07) paragraph [0002] - paragraph [0003] paragraph [0028] paragraph [0038] - paragraph [0039] figure 5	1,11

A	XAVIER PEÌ REZ-COSTA ET AL: "IEEE 802.11E QoS and power saving features overview and analysis of combined performance [Accepted from Open Call]", IEEE WIRELESS COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 17, no. 4, 1 August 2010 (2010-08-01) , pages 88-96, XP011316610, ISSN: 1536-1284 the whole document	1,11

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Information on patent family members

International application No
PCT/EP2011/004428

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