(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 June 2001 (07.06.2001)

PCT

(10) International Publication Number
WO 01/41371 A1

(51) International Patent Classification[7]: H04L 12/28, H04Q 7/22

(21) International Application Number: PCT/SE00/02450

(22) International Filing Date: 6 December 2000 (06.12.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
99850193.6 6 December 1999 (06.12.1999) EP

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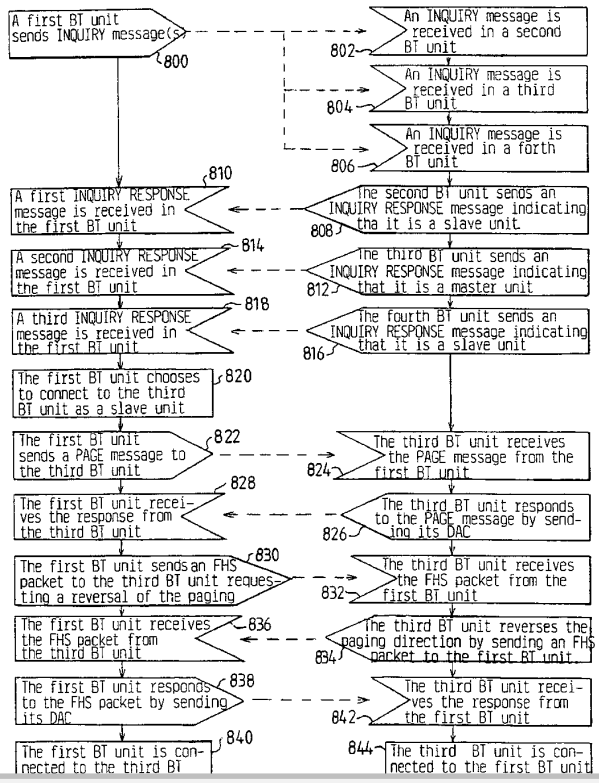
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European

[Continued on next page]

(54) Title: INTELLIGENT PICONET FORMING



(57) Abstract: When connecting a unit to one or more existing ad hoc wireless networks comprising several units, the units e.g. adapted to communicate according to the Bluetooth specification and the network then being formed according to the same specification to comprise one or more piconets, a unit can discover the units which are the masters in the networks, and then connect as a slave to those masters. Specifically it does not have to use the master-slave switch according to the Bluetooth specification. In the first stage of the unit trying to make a connection it establishes contact with at least one unit in an existing ad hoc network and then additional information on the status, in particular the role of master or slave, of the unit already connected in the network is transferred to the not yet connected unit. This information facilitates the decision of the unconnected unit as to which unit in the network that is should try to connect to. Then, in the actual connecting of the unit to the network, the roles of the unit and of the already connected unit can be chosen by the unit wanting to be connected. In particular, the initially inquiring and paging unit may become a slave unit in a newly formed piconet or in an already existing piconet.

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patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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Published:

— *With international search report.*

Intelligent piconet forming

The present invention relates to forming ad hoc wireless networks, more particularly to ad hoc networks formed according to the Bluetooth specification, and connecting a unit to an already existing ad hoc network.

BACKGROUND

Bluetooth (BT) is a relatively new specification for wireless communication of data and voice based on a low-cost short-range radio link. It can be built into a 9x9 mm microchip, what facilitates ad hoc connections for both stationary and mobile communication environments. Information in this application is in part based on the Bluetooth specification, "Specification of the Bluetooth System", July 26th 1999, the entirety of which is hereby incorporated by reference.

The original intention in making the specification of Bluetooth was to eliminate cables between telephones, PC-cards (Personal Computer cards), wireless headsets, etc., but today the Bluetooth specification is used for establishing true ad hoc wireless networks intended for both synchronous traffic, e.g. voice, and asynchronous traffic, e.g. data traffic based on the IP (the Internet Protocol). Now the intention of the Bluetooth specification comprises that any commodity device such as telephones, personal digital assistants (PDAs), laptop computers, digital cameras, video monitors, printers, fax machines, etc. should be capable of communicating over a radio interface, i.e. any of these devices could contain a radio chip made according to the Bluetooth specification and having the software specified therefor.

In addition to merely replacing the cables between various devices, the use of the Bluetooth specification in various device provides a bridge to existing data networks and their peripheral devices, and a mechanism to form small private ad hoc groupings for connected devices away from fixed network structures or connected to a fixed network structure via a gateway. According to the Bluetooth specification the wireless communication uses a fast acknowledgement and frequency hopping scheme to make the radio links between devices adapted to communicate according to the Bluetooth specification robust. The devices avoid interference with one another by hopping to a new frequency or channel after transmitting or receiving a packet. Compared to other systems operating in the same frequency band, in the wireless communication according to the Bluetooth specification typically frequency hops are made faster and shorter packets are used. The radio band used by devices adapted to communicate according to the Bluetooth specification is the unlicensed 2.4 GHz Industrial-Scientific-Medical (ISM) band with a channel spacing of 1 MHz.

A device adapted to communicate according to the Bluetooth specification includes a radio unit, a link control unit and a support unit for link management and host terminal interface function. According to the specification a point-to-point connection can be provided in the case, where only two units adapted to communicate according to the

several units adapted to communicate according to the Bluetooth specification. Two or more units adapted to communicate according to the Bluetooth specification form a small network called a piconet, see Figs. 1a - 1c. Within a piconet, a unit adapted to communicate according to the Bluetooth specification can have either of two roles: it can be a master or a slave. Within each piconet there may be only one master and one slave, see Fig. 1a, or more than one up to seven active slaves, see Fig. 1b. Any unit adapted to communicate according to the Bluetooth specification can become a master in a piconet.

Furthermore, two or more piconets can be interconnected, forming a composite network called a scatternet, see Fig. 1c. The connection point between two piconets consists of a unit C adapted to communicate according to the Bluetooth specification that is a member of both piconets. A unit adapted to communicate according to the Bluetooth specification can simultaneously be a slave member of multiple piconets, but only a master in one piconet, and thus a unit adapted to communicate according to the Bluetooth specification and acting as a master in one piconet can participate in other piconets only as a slave. A unit adapted to communicate according to the Bluetooth specification can only transmit and receive data in one piconet at a time, and therefore participation in multiple piconets is made on a time division multiplex basis.

The Bluetooth specification provides full-duplex transmission built on slotted Time Division Duplex (TDD), where each slot is 0.625 ms long. The time slots are numbered sequentially using a large number range, which is cyclic with a cycle length of 227. Master-to-slave transmission always starts in an even-numbered time slot while slave-to-master transmission always starts in an odd-numbered time slot. The combination of an even-numbered time slot and its subsequent odd-numbered time slot is called a frame, the frame thus including a master-to-slave time slot and a slave-to-master time slot, except in the case where multi-slot packets are used and longer frames are used. There is no direct transmission between slaves, neither within a piconet or between two different piconets.

The communication within a piconet is organised such that the master polls each slave according to some polling schedule. With one exception, a slave is only allowed to transmit after having been polled by the master. The slave will then start its transmission in the slave-to-master time slot immediately following the packet received from the master. The master may or may not include data in the packet used to poll a slave. The only exception to the above principle is that when a slave is connected by an established Synchronous Connection Oriented (SCO) link it is always allowed to transmit in the pre-allocated slave-to-master time slot, even if not explicitly polled by the master in the preceding master-to-slave time slot.

Each unit adapted to communicate according to the Bluetooth specification has a globally unique 48-bit IEEE 802 address. This address, called the Bluetooth unit Address (BD_ADDR), is assigned at the time when the unit is manufactured and it is never changed. In addition thereto the master of a piconet assigns a local Active Member

Address (AM_ADDR) to each active slave member of the piconet. The AM_ADDR, which is only three bits long, is dynamically assigned and de-assigned and is unique only within a single piconet. The master uses the AM_ADDR when polling a slave in a piconet. However, when the slave, triggered by a packet from the master addressed using the AM_ADDR of the slave, transmits a packet to the master, it includes its own AM_ADDR and not the AM_ADDR of the master in the packet header since an AM_ADDR of the master does not exist. Thus, the master of a piconet never assigns an AM_ADDR to itself.

Although all data are transmitted in packets, the packets can carry both synchronous data, on the mentioned Synchronous Connection Oriented links, mainly intended for voice traffic, and asynchronous data, on Asynchronous ConnectionLess (ACL) links. An SCO link is a symmetric point-to-point link between the master and a specific slave. The SCO link reserves slots and can therefore be considered as a circuit-switched connection between the master and the slave. An ACL link is a point-to-multipoint link between the master and all the slaves participating in the piconet. Slots may be reserved for SCO links, as indicated above, and in slots not reserved for such links the master can establish an ACL link on a per slot basis to any slave. The ACL link provides a packet-switched connection between the master and all active slaves participating in the piconet.

Depending on the type of packet used, an acknowledgement and retransmission scheme is used to ensure reliable transfer of data, such a scheme not being used for packets on SCO links transferring synchronous data. Forward error correction (FEC) in the form of channel coding is also used which limits the impact of random noise on long-distance links.

The standard format of a packet used for transmission according to the Bluetooth specification is illustrated in Fig. 2, this format not being used for some types of control packets. A standard packet has a field for an access code having the length of 72 bits and a header field of a length of 54 bits. There is a field for the payload which has a length that can range from zero to a maximum of 2745 bits. The AM_ADDR is located in the packet header followed by some control parameters, e.g. a bit indicating acknowledgement or retransmission request of the previous packet, when applicable, and a header error check (HEC).

The access code used in a packet can be one of three different types: Channel Access Code (CAC), Device Access Code (DAC), and Inquiry Access Code (IAC):

- The Channel Access Code identifies a channel that is used in a certain piconet, i.e. essentially the CAC identifies the piconet. All packets exchanged within a piconet carry the same the CAC. The CAC is derived from the BD_ADDR of the master unit of the piconet.

- The Device Access Code is derived from a BD_ADDR of a particular unit adapted to communicate according to the Bluetooth specification. It is used for special signalling procedures, e.g. the PAGE procedure

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