

Wireless Communications Link

Field of the Invention

The invention relates generally to the field of communications network. In particular, the present invention relates to wireless-communications in a local area network.

Background

Today, there are few computers, if any, that are not connected or connectable to other computers or devices. The concept of connectivity between computers and between computers and other devices subsists for the most basic reason that computers deal or work with data. The data must therefore be provided to computers from some extrinsic source. A simple example is the copying of files from floppy disks into computers, whereby the files themselves have been copied from other computers or devices. Another example is the downloading of files from the Internet. Having dealt with or worked on the data, computers sometimes provide the processed data to other computers or other devices for further processing or storage. Using the same examples, the processed data can be copied via floppy disks, or transferred via the Internet, to other computers. Computer connectivity is therefore an essential aspect of the subsistence of computers.

The form of computer connectivity has evolved to such an extent that the connections between computers and between computers and other devices are no longer bound or limited by geography. The sharing of information through data communications can be achieved, for example, by simply having a computer user connect the computer to a telephone line and dial-up an Internet service provider of which the user is a subscriber. Having done so, the computer user is then able to access the Internet. When connected to the Internet, the computer user can, through his computer, do a myriad of things. The computer user can, for example, download a file from an Internet website that is sited in a continent separated from the computer user by oceans and seas. The computer user can

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also communicate via e-mail with another computer user in yet another continent. Such examples, by virtue of the reach of computer connectivity, clearly show the usefulness and importance of computer connectivity.

The concepts of computer connectivity and data communications are not mutually exclusive. In fact, computer connectivity is meaningless without data communications, and vice versa. Data communications allow the exchange of information in forms or representations that are carried in the connections between computers and between computers and other devices.

Data communications and computer connectivity today form part of an essential service in the form of computer networking to computer users for enabling the sharing of information among computer users. An example of a computer network is a Local Area Network (LAN) where a collection of computers and network devices is located within a geographical area. These computers and network devices are interconnected in such a way that information among the computers and network devices is shared as a common resource. Typical places where a LAN may be found are campuses or offices where the campuses or offices are defined by the boundaries within which campus education or office work take place. In an office, the boundary is typically the walls defining the extremities of the office. The staff in the office can therefore access information that is shared out via the LAN through computers that are part of the LAN.

Alongside the development of computer networking technology, computer technology has evolved to a state where the miniaturization of electronic components for computers has allowed for the corresponding miniaturization of computers into portable computers. Computers can be built much smaller in size than before and can therefore be easily carried around. This evolution in computer technology bodes well for the modern society because society has sophisticatedly evolved and thus the nature of modern jobs and vocations has radically changed, using again the above example. Office workers are no longer bound to a particular desk, but are often required to move around within the office. Work for example can be done in one part of the office as well as another part of

the office. Taking again the other example, campus education is no longer confined to classrooms, and students are no longer confined to classroom seats.

Where there is a LAN in an office, the office workers therein may use computers connected to the LAN for accessing shared information. However, if the computers connected to the LAN within the office are connected via physical-line communications connections, for example cables or wires, office workers are consequently restricted as to where they can do their work using the computers. They can only work at desks in the office where computers are available and these computers are connected to the local area network. Similarly, in campuses where the computers in classrooms are connected to a LAN by physical-line communications connections, students are bound to classroom seats where access points to the LAN are provided.

Taking advantage of modern technology, LANs today are implemented with a combination of computers that are connected to the LAN via physical-line communications connections and portable computers that are connected to the network via wireless communications connections. Examples of wireless communications connections are optical communications connections and Radio Frequency communications connections.

One conventional approach to implementing a LAN with a combination of physical-line and wireless communications connections involves the use of Infrared optical communications technology. In such an implementation, there are several portable computers connected to the LAN by way of Infrared optical communications connections, forming one or more wireless communications portion or cell in the LAN, in addition to the computers connected to the LAN by way of physical-line communications connections. These portable computers are fitted with Infrared optical communications transceivers. A transceiver for a particular wireless communications connection is a device for transmitting and receiving data in a form and manner prescribed for that wireless communications connection. For accessing the LAN, the portable computers within a wireless cell first communicate with a base unit, which is for these portable computers an access point to the resources on the LAN. The base unit,

which is also fitted with an Infrared optical communications transceiver compatible with the transceivers in the portable computers, in turn communicates with the LAN by way of a physical-line communications connection. In terms of functionality, therefore, the base unit collects requests for information from the portable computers and distributes requested information to the portable computers through the wireless communications connections.

In another conventional approach to implementing a LAN with wireless cells, Radio Frequency communications technology is used. The main difference between such an implementation and the preceding implementation lies in the different wireless communications technologies used.

In both instances where conventional wireless communications technologies are used in wireless cells in LANs, inherent disadvantages and shortcomings can be found. One such disadvantage is that these conventional wireless communications connections are typically oversized. The data traffic handling capability of these conventional wireless communications connections is the same regardless of whether data is transmitted from the base unit to the portable computer, the downlink, or from the portable computer to the base unit, the uplink. That is, these conventional wireless communications connections are designed so that the downlink carries data traffic at the same capacity and rate as the uplink. In normal circumstances, the downlink usually deals with heavier data traffic than the uplink. This is because a portable computer usually only transmits requests for information or files thereby causing the respective resources in the LAN to download large amounts of data to the requesting portable computer. Hence, the uplink data traffic capacity and rate is not optimally exploited. In such circumstances, either Infrared optical or Radio Frequency communications connections is deemed as being oversized and therefore is not cost effective.

Although substantial miniaturization of computers has occurred at a rapid pace, the power requirements or needs of these portable computers still have not been met adequately. That is, these portable computers indispensably rely on battery power but the technology for battery life prolongation has not progressed at the same pace as the

miniaturization of computers. At best, therefore, a portable computer provides 10 to 15 hours of continuous computer usage time. However, when these portable computers are fitted with auxiliary devices such as transceivers for wireless communications connections, the power from the battery is drained more rapidly thereby leaving a lesser computer usage time in the portable computers.

In addition, the performance of transceivers for wireless communications connections is generally dependent on the power that is supplied. In the case of transceivers fitted to portable computers, the power supplied is that which is shared with the host portable computers. Most power management modules in portable computers dictate that power be sparingly and conservatively consumed. A practical problem arises when these transceivers for wireless communications connections are applied in constrained power supply situations to provide data communications at high transfer rates. Transceivers for providing data communications at high transfer rates are typically adversely affected in terms of data transmission accuracy, by the constrained power supplied by the power management modules of portable computers. This is because the transmitters in these transceivers transmit data by producing signals using the available power supplied. If the power supplied is low, the transmitted signal is weak and thus for obvious reasons has a higher data error rate than a signal transmitted by transceivers without power constraints. This leaves very little room for design freedom vis-a-vis cost effective development of wireless communications connections. Existing commercial wireless communications connections products available provide complicated hardware for transceivers that are used in both the base unit and the mobile computers, and therefore clearly do not address the data transmission accuracy issue.

In order to separate the downlink and uplinks, these commercial products also provide only half-duplex wireless communications connections since the same frequency is typically used for transmitting data in the downlink and uplinks.

Clearly, a need exists for a new and improved form of wireless communications connection that addresses the above disadvantages of overdesign, cost ineffectiveness,

data transmission accuracy, half-duplex communication, and rapid power drain from portable computers.

Summary

According to a first aspect of the invention, there is provided a method of exchanging data between network entities in a Local Area Network through wireless communications media. The method includes the steps of: transferring data from a first entity to a second entity using a first wireless medium, and from the second entity to the first entity using a second wireless medium; and transmitting data from the first and second entities at independent data transfer rates.

Preferably, the transferring step includes the step of exchanging data between the first and second entities, where the first entity is connected to a physical-line communications portion of the Local Area Network. The transferring step includes transferring data from the first entity to the second entity using optical communications, which is more preferably Infrared optical communications.

Still further, the transferring step further includes transferring data from the second entity to the first entity using Radio Frequency communications.

Optionally, the transferring step further including exchanging data between the first and second entities wherein the second entity is a portable device. Further, the first and second wireless communications media form a full-duplex wireless communications.

According to a second aspect of the invention, there is provided a wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion. The system includes: a first transceiver, a second transceiver and a connection between the first entity and the physical-line portion of the Local Area Network. The first transceiver for connection with a first entity transmits and receives data by means of first and second wireless media. The first wireless medium is used for transferring data from the first entity to a second entity and

the second wireless medium is used for transferring data from the second entity to the first entity. The second transceiver for connection with a second entity transmits and receives data by means of the first and second wireless media.

According to a third aspect of the invention, there is provided a transceiver for use in a base unit of a wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion. The transceiver includes: a device for transmitting data via a first wireless medium; a device for receiving data via a second wireless medium; and a device for connecting the base unit with the physical-line portion of the Local Area Network.

According to a fourth aspect of the invention, there is provided a transceiver for use in a client or mobile unit of a wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion. The transceiver includes: a device for receiving data via a first wireless medium; and a device for transmitting data via a second wireless medium.

Brief Description of the Drawings

Embodiments of the invention are described hereinafter with reference to the drawings, in which:

Fig. 1 is a high-level block diagram illustrating the implementation of hybrid wireless communications connections, according to a preferred embodiment of the invention, in a wireless cell of a LAN;

Fig. 2 is a block diagram illustrating the components in a base unit shown in Fig. 1 for providing the hybrid wireless communications connections;

Fig. 3 is a block diagram illustrating the components in a client shown in Fig. 1 for providing the hybrid wireless communications connections;

Fig. 4 is a contextual diagram of a campus LAN having the wireless cells and implementing the hybrid wireless communications connections shown in Fig. 1;

Fig. 5 illustrates the communications protocol stack in accordance with the embodiment of Fig. 1; and

Fig. 6 is a timing diagram illustrating a registration scenario.

Detail Description

A method, a system, a transceiver of a base station and a transceiver for a client or mobile station for providing a hybrid wireless communications connection suitable for use in a LAN are described. In the following description of several embodiments, information on the International Organization for Standardization Open System Interconnection model (ISO/OSI), Infrared optical communications technology, Radio Frequency communications technology, and the like are provided in order to present a more thorough description of these embodiments. To one skilled in the art, however, the invention may be practiced without those specific details. In other instances, well known details such as networking technology, Internet technology, various physical-line communications connections, and the like are not provided in detail so as not to obscure the invention.

There are many advantages of the embodiments of the invention. First of all, the embodiments of the invention address the problem of overdesign in conventional approaches wireless communications connections. By taking into account the difference in the requirement for uplink and downlink data traffic capacity and rate, the uplink and downlink are separated in the hybrid wireless communications connections provided by the embodiments of the invention. As the downlink typically carries heavier data traffic, the downlink is specifically designed to handle high data traffic in the embodiments of the invention. On the other hand, the uplink is designed to carry a lower data traffic. Secondly, the embodiments of the invention address the issue of low power supply in the portable computers. By implementing the downlink using Infrared optical communication technology. An Infrared communications transmitter is thus fitted in the

base unit, and an Infrared optical communications receiver is thus fitted to the portable computers. Generally, Infrared optical communications receivers consume little power and therefore are ideal for use with the portable computers. The complex circuitry and high power requirement of an Infrared optical communications transmitter can be placed in the base unit where power supply and size do not pose as a problem for the base unit. The uplinks are implemented using Radio Frequency communications technology. Thus a Radio Frequency communications transmitter, which is a low power device, can be fitted to the portable computer while a more complex Radio Frequency communications receiver is fitted to the base unit. Such an approach to practicing the embodiments of the invention is well suited for purposes of addressing the power supply issues in the portable computers. Additionally, an advantage gained is the implementation of simple hardware for the transceivers in the portable computers. Over and above the two advantages, which adequately address the problems associated with conventional wireless communications implementations in conventional LANs, the embodiments of the invention also address the issue of half duplex wireless communications. By providing a hybrid wireless communications connection using different uplink and downlink wireless communications technology, the embodiments of the invention ensure a full duplex wireless communications.

By reference to Fig. 1, the underlying principle for the embodiments of the invention is described. A portion of a LAN, generally designated with a numeral 10, is shown in Fig. 1. The portion of the LAN 10 shown in Fig. 1 includes a base unit 12 connected to a fixed network 14. The fixed network 14 is a conceptual representation of network elements of the LAN 10 which are interconnected using physical-line communications connections. The base unit 12 is also connected to the fixed network 14 by a physical-line communications connection. During operation of the LAN 10, clients 16a, 16b, and 16c (for e.g., portable computers fitted in the transceivers for the hybrid wireless communications connects) are able to access the resources on the LAN 10. Such resources are for example, other computers connected to the LAN 10 via physical-line communications connections or printers, scanners, and the like devices which are also connected to the LAN 10 via physical-line communications connections. The clients 16a, 16b, and 16c communicate with the LAN 10 via the base unit 12. The client 16a

communicates with the base unit 12 via an uplink channel 18a and a downlink channel 19a. Similarly, the client 16b communicates with the base unit 12 via an uplink channel 18b and a downlink channel 19b. By the same token, the client 16c communicates with the base unit 12 via an uplink channel 18c and a downlink channel 19c. The uplink channels 18a, 18b, and 18c are implemented with the same type of wireless technology. In addition, the downlink channels 19a, 19b, and 19c are implemented using the same type of wireless communications technology. Examples of wireless communications technology are the Infrared and Radio Frequency communications technologies.

In such an arrangement, the client 16a can communicate with the LAN 10 through the base unit 12 via the uplink channel 18a regardless of any traffic situation in the downlink channel 19a, 19b or 19c. This is the advantage of a full duplex system over the half-duplex system as mentioned in the foregoing for the conventional LAN implementations. In the half-duplex wireless communications systems, if one client 'hogs' the uplink wireless communications connections, a base unit would not be able to communicate with the other clients for obvious reasons. Hence, the benefits conferred by the embodiments of the invention are accentuated in this respect.

Hybrid Wireless Communications Connections

By making reference to Fig. 2 and Fig. 3, a preferred embodiment of the invention is described. Fig. 2 illustrates the components in the base unit 12 as shown in Fig. 1. These components relate to the operation of the uplink channels 18a, 18b and 18c, and the downlink communication channels 19a, 19b, and 19c. In the preferred embodiment, the uplink channels 18a, 18b, and 18c are implemented using Radio Frequency communications technology. On the other hand, the downlink channels 19a, 19b and 19c are implemented using Infrared communications technology. By doing so, the effect of separating the uplink channels 18a, 18b and 18c from the downlink channels 19a, 19b and 19c is achieved.

A Radio Frequency antenna 22 is implemented in the base unit 12 for receiving Radio Frequency waves or signals that provide the uplink channels 18a, 18b, or 18c. The base

unit 12 also has an Infrared optical emitter 24 for transmitting Infrared light that provides the downlink channels 19a, 19b, and 19c.

In using Radio Frequency wireless communication technology for the uplink communication channel 18a, 18b, and 18c, the preferred embodiment provides a further advantage. This advantage confers a safety benefit to users of the clients 16a, 16b, and 16c. Conventional approaches of implementing wireless communications such as the single medium Infrared communications technology are imposed with eye-safety distancing constraints. Regulatory bodies in various jurisdictions typically regulate the strength of Infrared transmitters. By using Radio Frequency communication technology on the clients 16a, 16b, and 16c, conformance with the eye-safety standards are avoided.

When Radio Frequency signals are received by the Radio Frequency antenna 22, the Radio Frequency signals are provided as input to a radio frequency receiver module 26. These Radio Frequency signals can come from any one of the clients 16a, 16b, or 16c. When using radio frequency communications technology, it is considered good practice to spread the frequency spectrum of the Radio Frequency signal transmitted by the transceiver of the portable computers by a given factor. In some jurisdictions, for example the United States, there exist regulations prescribing requirements of how the frequency spectrum of transmitted Radio Frequency signals is spread. In relation to the industrial, scientific and medical instrument frequency (ISM) band, the Federal Communications Commission (FCC) in the United States has imposed specific rules and conditions for the utilization of such a frequency band. The ISM frequency band is reserved for the use and operation of industrial, scientific and medical instruments. However, the FCC has recently indicated that the ISM frequency band may be utilized for purposes such as for enabling computers in LANs to communicate with each other.

Specifically, the FCC prescribes that in order to use and share the ISM frequency band for communication purposes, the frequency spectrum of the Radio Frequency signal used for LAN must be spread by a factor of at least 10. One way of accomplishing this is to encode each bit of data with a predefined code word, or pattern, consisting of at least 10 "chips" or "signal elements". That is, for every one bit of data to be transmitted in X

seconds, 10 additional bits which make up the chips or signal elements must be added to that one bit of data and the 11 bits collectively must be transmitted in the same X seconds to represent that one bit of data. The Institute for Electrical and Electronic Engineers (IEEE), has developed a standard for communications for LANs in the ISM frequency band using the Barker code, which is well known to those skilled the art. The Barker code equivalent of a "1", or high, or set, bit is "00011101101". The complimentary "0", low, or unset, bit is represented by "11100010010". Alternatively, a unique code word may be chosen, which is different from the Barker code, so that the spreading of the frequency spectrum of the Radio Frequency signal used in communications for LAN accords with the IEEE 802.11 standards for wireless LAN technology.

Alternatively another method of utilizing and sharing the ISM frequency band for purposes of wireless communications applications in LAN is the use of frequency hopping. To achieve spreading of the frequency spectrum of Radio Frequency signals that are transmitted in a wireless communications LAN, frequency hopping in the 2.4 Ghz ISM frequency band is proposed by the FCC. The 2.4 Ghz ISM frequency band is divided into 82 different frequency channels spaced at 1 Mhz intervals. Therefore, the transmission of Radio Frequency signals in wireless communications for LAN can be done utilizing any of the 82 different frequency channels.

The representation of a "1" or "0" in a Radio Frequency signal is achieved by utilizing the Phase-Shift Keying (PSK) modulation scheme. To those skilled in the art, this modulation scheme is but one of many data representation schemes used for Radio Frequency signaling. Typically, the Quadrature Phase-Shift Keying (QPSK) modulation scheme is used, where the phase of the Radio Frequency signal is shifted in multiples of 90 degrees. By doing so, four possible signal states and therefore 2 bits of data may be represented by each phase when using the QPSK modulation scheme.

Typically, Radio Frequency transceivers for supporting frequency hopping to achieve the spreading of frequency spectrum are built for data transmission at the data transfer rate of 1 Mbps. This is to accord with Part 15.247 of the FCC rules, which governs the ISM

frequency band. These Radio Frequency transceivers can be tuned to any one of the 82 different frequency channels spaced at 1 Mhz intervals. Therefore, the first two frequency channels are 2.401 Ghz and 2.02 Ghz. The last 2 frequency channels are 2.481 Ghz and 2.482 Ghz. Also, the typical range between transceivers is approximately 150 feet in a typical office enclosure. To those skilled in the art, a typical office enclosure is one that has heat rock walls that attenuates the Radio Frequency signals at a square law power fall off for the first three meters and a fourth law fall off thereafter. In the preferred embodiment, the transmitted power output of the Radio Frequency transceivers is approximately +17dbm and the receiver sensitivity in the transceivers is approximately -85dbm. Numerous other essentially equivalent arrangements will be apparent to those skilled in the art in view of this disclosure.

In the preferred embodiment, each of the uplink channels 18a, 18b or 18c is a division of the Radio Frequency signals according to the Frequency Division Multiple Access-Time Division Multiple Access (FDMA-TDMA) by polling scheme. By this, it is meant that the Radio Frequency signal transmitted at a particular frequency or using a unique pseudo code in the ISM frequency band is divided up into frequency bands and into time units or divisions. Each of these time units or divisions is allocated to each of the client 16a, 16b or 16c. Hence, by association with the data transmitted within the each of these time units or divisions, the base unit 12 is able to recognize data transmitted by any of these clients. The Radio Frequency antenna 22 and the Radio Frequency receiver module 26 are therefore built to receive Radio Frequency signals at a prescribed frequency or a unique pseudo code in the ISM frequency ban.

The Radio Frequency antenna 22 can be either a single or multiple antenna system, which is strategically placed on the base unit 12 for adequate reception of the radio frequency signals. A multiple antenna system may be used for diversity reception purposes. In the Radio Frequency antenna 22, a low noise amplifier is used with each antenna for achieving a suitable signal amplification gain and a good noise figure.

The Radio Frequency signal having been processed by the Radio Frequency antenna 22 is subsequently processed by the Radio Frequency receiver module 26. In the Radio

Frequency receiver 26, the Radio Frequency signal is amplified. Frequency channel selection and down conversion to a corresponding Intermediate Frequency (IF) signal are performed. Equalization, bit detection and correction may also be performed if required (when the Radio Frequency signal is provided with forward correction codes embedded in the information bits). The demodulation function, which accords with the type of modulation scheme adopted in the preferred embodiment is then carried out. Preferably, binary phase shift keying (BPSK) is used as the modulation/demodulation scheme, although numerous other schemes may be practiced without departing from the scope and spirit of the invention.

The Radio Frequency signals having been stripped of the Radio Frequency carriers and subsequently demodulated consequently becomes data that is input to a medium access controller 20. The media access controller 20 receives data from the Radio Frequency receiver 26 and performs error detection and correction. The media access controller 20 also is responsible for managing a communications protocol in conjunction with corresponding media access controllers 30 in the clients 16a, 16b, and 16c. The media access controller 20 is also responsible for providing a different Infrared optical transmitter 28 with data from the fixed network 14. The different Infrared optical transmitter 28 performs error protection coding on the data before providing the data to the optical Emitter 24. The different Infrared optical transmitter 28 also performs the modulation of the data on a carrier using an optical modulation scheme, such as the pulse position modulation scheme (PPM).

The Infrared signal transmitted by the optical emitter 24 of the base unit 12 is also divided up into divisions forming the downlink channels 19a, 19b, and 19c. In the preferred embodiment, this division or units are divided up by using the Time Division Multiple Access scheme. Each time division or unit is recognized by each of the clients 16a, 16b or 16c by a matching address. The matching address is part of the data carried in that time division or unit that represents the identity of each of the client 16a, 16b, or 16c.

The optical emitter 24, after receiving data from the diffused optical transmitter 28, transmits Infrared signals in an omni-directional manner to any of the client 16a, 16b, or 16c. The optical emitter 24 is typically an array of solid state semiconductor Light Emitting Diodes (LED). To those skilled in the art, Infrared signals are radiated at the invisible portion of the light spectrum.

Reference is made to Fig. 3 to describe the components in any of the clients 16a, 16b, or 16c. An optical detector module 32 found on any of the client 16a, 16b, or 16c is provided to receive the Infrared signals transmitted by the optical transmitter module 24 in the base unit 12. The optical detector 32 is also an array of solid state semiconductor light detection devices sensitized to radiation at the invisible portion of the light spectrum. Having received the Infrared signal, the optical detector module 32 subsequently amplifies the Infrared signal using an appropriate amplifier and performs automatic gain control so that Infrared signals at varying signal strengths can also be accommodated.

The optical detector module 32 provides as input the pre-amplified signal to a diffused optical receiver 36. The diffused optical receiver 36 demodulates the pre-amplified signal and performs demodulation such as PPM demodulation. Also, the diffused optical receiver 36 performs error detection and error correction of the pre-amplified signal using embedded forward correction bits in the information bits of the pre-amplified signal. The diffused optical receiver 36 provides as input the demodulated and error-corrected data to the medium access controller 30. The media access controller 30 subsequently checks the address carried by on the data to determine if it is addressed to the particular client in which the media controller 30 resides. If the address is matched with the address assigned to the particular client, the media access controller 30 passes the data to the other portions of the particular client for further processing. Examples of further processing include verifying a CRC code, extracting a data payload, and the like.

When the client 16a, 16b, or 16a has information or a request to make to any of the other computers in the LAN 10 through the base unit 12, the client 16a, 16b, or 16c transmits a stream of data to the media access controller 30. The client 16a, 16b or 16c must do so

in accordance with the instruction received from the base unit 12 in relation to the time division or unit which the client 16a, 16b or 16c is allotted to transmit data to the base unit 12. The media access controller 30 accordingly schedules the transmission of the data from the client 16a, 16b, or 16c.

When the appropriate time to transmit the data to the base unit 12 is reached, the media access controller 30 passes the data to a Radio Frequency transmitter 38. The Radio Frequency transmitter 38 amplifies the error protection coding on the data to be transmitted. One example of error coding protection that can be used include CCITT CRC 16 with a polynomial, $g(D)=D^{16} + D^{12} + D^5 + 1$. The Radio Frequency transmitter 38 also modulates the data according to the modulation scheme. Again, the preferred modulation scheme is BPSK. Subsequently, the data is upconverted to a Radio Frequency signal for a particular Radio Frequency channel according to the frequency-hopping scheme. Alternatively, the data is spread using a chosen pseudo-random code sequence in accordance with the spreading of the frequency spectrum of a transmitted Radio Frequency signal by a given factor.

The upconversion of the data to the Radio Frequency signal is performed so that the Radio Frequency signal is in the 2.4 Ghz ISM frequency band. The radio frequency signal is subsequently amplified to a power level suitable for covering the service zone, such as 0dbm, or 20dbm. The Radio Frequency signal having been processed by the Radio Frequency transmitter 38 is provided as input to a Radio Frequency antenna module 34. The radio frequency antenna module 34 may contain one or more multiple antennas. The multiple antennas are strategically placed on the client 16a, 16b, or 16c for diversity transmission. The matching circuitry associated with each antenna performs load matching to achieve effective radiation of the Radio Frequency signal.

A Campus LAN Using The Hybrid Wireless Communications Technology

To further describe, and therefore provide an appreciation of, the preferred embodiment, an implementation of hybrid wireless communications connections in the context of the LAN for a campus is described. Fig. 4 is a contextual diagram of the campus LAN. The campus LAN consists of a campus backbone 40, a library cell 41, a conference hall cell

42, a LAN switch 43, a classroom 1 cell 44, and a classroom 2 cell 45. For connectivity to other resources such as the Internet 46, the campus LAN is connected to the Internet 46 via the campus backbone 40. In this example, the physical-line portion of the campus network includes the library cell 41, the conference cell 42, the LAN switch 43, and the campus backbone 40. These physical-line campus LAN resources provide and/or collect information that is shared throughout the campus LAN. In order for the classroom 1 cell 44 and the classroom 2 cell 45 to access the information shared out on the campus LAN, the LAN switch 43 is provided. Connectivity between the LAN switch 43 and the classroom 1 cell 4, classroom 2 cell 45 is by physical-line communications connections. Within each of the classroom cell, however, connectivity between network devices 47 and access points 48 is based on the preferred embodiments hybrid wireless communications connections. That is, each of the network device 47 within a particular classroom cell is connected to the access point 48 in the same classroom cell via the preferred embodiment wireless communications connections.

Each classroom cell is an independent and geographically isolated classroom cell. Hence classroom 1 cell 44 is located at a different place from classroom 2 cell 45 and each are defined by walls that are impenetrable to Infrared radiation. In this respect, the frequency on which the downlink channels using Infrared communications technology subsist can be reused in every classroom cell. However, because Radio Frequency signals may penetrate and transcend walls separating classroom cells, the frequency on which the uplink communication channels are carried cannot be reused in every classroom cells, especially in neighboring classroom cells. Classroom 1 cell 44 is therefore provided with uplink communication channels carried on an ISM frequency channel, which is different from that used in the classroom, 2 cell 45.

In each classroom cell, the access point 48 is designed to provide hybrid wireless communications connectivity for up to forty network devices 47. In this campus LAN implementation, the design is directed to maximizing the performance of data transfer of applications, which are based on the Hypertext Transfer Protocol (HTTP). An example of an HTTP application is a web page that can be downloaded from a website on the Internet 46. In such downloading applications, the bulk of the data traffic flows in one

direction, i.e., from the Internet 46 to the campus backbone 40, to the LAN switch 43, to the access point 48 in the respective classroom cell, and then to the respective network device 47 from which the request for information was made.

In such an implementation, the benefits of the preferred embodiment are accentuated. The ensuing description is dedicated to a design overview of a preferred embodiment hybrid wireless communications protocol used within each classroom cell. Specific details of implementation are provided hereinafter for a better appreciation of the implementation of the hybrid wireless communications technology in the campus LAN described in the foregoing. However, the description is by no means exhaustive in nature and thus should not be construed as limiting on the invention. To a person skilled in the art, the ensuing description serves to provide one possible way of implementing the hybrid wireless communications protocol in accordance with the ISO/OSI model. However, other implementations are possible without having regard to the ISO/OSI model and yet not depart from the scope and spirit of the invention.

Classroom Cell Sub-Network

Each classroom cell forms an independent sub-network that is connected to the LAN switch 43 and hence to the campus LAN, and is hereinafter referred to as an Infrared Multi-access Multicast Network (IM2NET). In conformance with the ISO/OSI model, a Media Access Controller (MAC) in the Access Points (APs) 48 and the Network Devices (NDs) 47 in each classroom cell provides the functionality of a Data-Link Layer, while a transceiver in the APs and the NDs in the same classroom cell provides the functionality of a Physical Layer. The Data-Link Layer and the Physical Layer are the two lowest layers in ISO/OSI model. Therefore, the MACs and the transceivers form the two lowest layers of the communication protocol stack in each IM2NET.

Physical Layer

The physical layer of the IM2NET communication protocol stack is described hereinafter. In particular, the requirements of the Physical Layer by the Data-Link Layer (IMA2MAC-1) are described. The IMA2MAC-1 is practiced with a full-duplex

uplink/downlink Physical Layer, which is provided by the hybrid wireless communications technology according to the preferred embodiment.

Each downlink communications channel is practiced using Diffused Infrared (DIR) technology. To take advantage of existing technology, each downlink communication channel preferably transmits data at 4 Mbps using the Far Infrared (FIR) encoding format specified in the Infrared Data Association (IrDA) Serial Infrared Physical Layer Link Specification. Lower data transmission speeds may be implemented to improve the bit error rate performance of each downlink communications channel.

Each uplink communications channel is practiced using Radio Frequency (RF) technology with several uplink frequencies, each IM2NET utilizing a unique frequency, to provide frequency separation between the classroom cells. The RF uplink communications speed may be set up to hundreds of Kbps.

A frame is a unit of transmission in relation to the IM2MAC-1 and includes the IM2MAC-1 header and data.

The uplink communications channel frame format is as follows (depending on the RF module that is implemented):

Preamble pattern	Frame
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The details of the preamble pattern, modulation and line encoding depend on the hardware that is selected for the Physical Layer implementation. The IM2MAC-1 protocol does not impose on the hardware on these issues.

Description of IM2MAC-1

Overview

The IM2AC-1 layer provides a mechanism to share access of the uplink communications channel among multiple (up to 40) NDs. The IM2MAC-1 also provides an interface for Network Layers to send and receive frames on both the uplink and the downlink

communications channels. The IM2MAC-1 also includes the functionality of a Logical Link Control (LLC) sub-layer. The Network Layer and the Logical Link Control sub-layer are also components of the ISO/OSI model. The schematic view of layered abstraction is illustrated in Fig. 5. The Internet Protocol 52(IP) layer and the EduPAD Control Protocol (ECP) are examples of Network Layers.

An AP broadcasts a beacon regularly to let NDs register themselves with the AP. Any ND must register with the AP before that ND can gain communications access. The registration mechanism is described hereinafter. If the ND has not registered, the ND must disallow Network Layer protocols in the ND from using the ND to access the LAN. After an ND has registered, the ND is allowed to send Network Layer packets on the uplink communications channel only after the AP has polled it. The AP is responsible for the scheduling the sending of data frames and polling requests to the NDs; address assignment of the NDs; and scheduling contention period for new NDs to register with the AP.

Order of Transmission of Bytes

For a multi-byte field of a frame, the order of transmission followed is big endian.

Except for data field of data frames and ND MAC address list field of beacon frame. For the former, the order is unspecified, and for the latter, individual addresses must be ordered in big endian format.

ND MAC Address

The protocol uses dynamic ND MAC address assignment scheme. The address is 4 bytes long with following format:

Control bits		Special address bits				Slot ID	Contention ID
T	R	0	0	A	M	1 byte	2 bytes

The Control bit is a nibble and this nibble is used by beacon frames and poll frame to indicate whether an ND MAC address specified in the ND MAC address list field is in the uplink list, downlink list, or neither. The uplink list is a list of clients that may

transmit data during the following beacon period. The downlink list is a list of NDs that receive data during the following beacon period. The T field has three bits to indicate the number packets the owner of the address can transmit. The address is included in uplink list if this number is greater than zero. R is set to indicate that the address is in the uplink, all the control bits are set to 0 otherwise.

The special address bit is a nibble and is used to distinguish AP address and multicast addresses from the normal ND address. Bit A is set to indicate that the address is an AP address; bit M is set to indicate that the address is a multicast address. Individual ND addresses should have both these bits set to 0. AP address is the MAC address of the Access Point.

The method of matching multicast Network Layer addresses to the MAC layer multicast address is determined by the Network Layer. A MAC layer implementation preferably provides a means for the Network Layer to register the multicast MAC addresses that the ND and AP should listen for.

The Slot ID is the real slot number in which the ND successfully registers. The ND address is assigned by the slot number and the contention ID of the contention duration in which the ND successfully registers.

The Contention ID is the contention ID of the contention duration in which the ND successfully registers.

By default, the IM2MAC-1 implementation preferably only pass frames the IM2MAC-1 receives with unicast MAC address up to the Network Layer. However, the implementation preferably also provides a mechanism for the Network Layer to set the IM2MAC-1 up for promiscuous mode (i.e. pass up ALL Network Layer data frames) or to receive certain multicast-addressed frames.

Special Addresses

A Broadcast address is used for addressing all the terminals, and the format is:

Control Bits				Rest of the address
0	0	0	0	All 1's

Frame Description

In general, the frame format consists of the following fields:

Destination address	Source address	Type	Length	Information	CRC
4	4	2	2	Variable	2

The Destination address field can be the address of an ND, AP, a multicast address or a broadcast address. In a downlink frame, this field can not be the address of an AP. In an uplink frame, this field can not be the address of an ND.

In a downlink frame, the source address field must be the address of the AP. In an uplink frame, this field must be the address of an ND. The Type field represents the type of frame (poll, IP, ECP, etc)

The Length field represents the number of bytes in the Information field. This field is not present in the registration request frame. The Information field contains an undefined number of bytes - depending on the frame type. The CRC (Cyclic Redundancy Check) field is the CRC value of all the above fields. An implementation must use the 16 bit CRC-CCITT. Note that this is a variation from the IrDA Serial Infrared Physical Layer Link Specification for the FIR transmission that uses CRC32 as specified in the IEEE 802 standard.

Network Data Frames (Uplink and Downlink)

The Network Data frames are used to carry Network Layer packets. The Type field indicates the upper layer protocol type.

Format:

Destination address	Source address	Type	Length	Network layer packet	CRC
4	4	2	2	Variable	2

Fields:

Type: All network data frames have types of form 0xfyyy or 0xeyyy. For IP packets, Type = 0xf001; for ECP packets, Type = 0xe001.

Length: this field should be up to a maximum of 1000 (TBD).

Beacon frame (Downlink only)

The Beacon frame serves a few purposes. Firstly, the Beacon frame announces the list of NDs that are registered with the AP and whether each of them can expect poll or network data frames from the AP in the following beacon period. Secondly, the Beacon frame broadcasts the contention period - this is the time that new NDs can register themselves with the AP.

Format:

Broadcast Address	AP address	Type = 0x00ff	Length	Version numbers	Contention ID	Number of cont. slots	Contention/uplink slot size
4	4	2	2	4	2	1	1

Uplink freqID	Beacon period(T_{st})	No. of addresses (N_a)	MAC address List	CRC
2	2	2	$4 \times N_a$	2

Fields:

Broadcast address: Addressed to all NDs. If a ND misses this frame, it needs to keep awake till it receives the next PDL/B frame.

Type: set to 0x00ff.

Version numbers: This field determines whether the ND can inter-operate with the AP.

The version number is a 2-tuple (M, N) where:

- M = protocol version number (2 bytes)

- N = minimum compatible protocol version number (2 bytes)

All the fields are in big-endian order as discussed in the foregoing. Hence, M is the most significant field. If a ND receives a beacon frame where the version number is lesser than the N value in the beacon frame, then the protocol implementations are incompatible -, i.e. the ND cannot register with the AP. If the ND receives a beacon frame where the protocol version number is greater than M, then the ND should determine within the ND's own code to see if the ND can inter-operate with the AP. The ND may not inter-operate with the AP if the ND determines that the ND does not have the implementation of that protocol. If the ND's protocol version number is between M and N (inclusive), then the protocol implementations are compatible. The current protocol version number discussed in this document is 0x0100.

Contention ID: The AP assigns a running count to this field in every contention beacon frame. In a non-contention beacon frame, the AP is assigning a value that is the same as the one used in the previous contention beacon frame. On receiving a contention beacon frame, an unregistered ND takes note of the ID if the ND is going to send a registration frame in the following contention period. An unregistered ND can ignore this field if the ND receives a non-contention beacon frame.

Number of contention slots: This field consists of two sub-fields, each a nibble wide. The upper nibble represents base 2 logarithm of the number of virtual slots that the ND should contend for. The lower nibble represents the base 2 logarithm of the number of contention slots available for this contention beacon frame. Hence, for example, 0x64 indicates that that there are $2^6 = 64$ virtual slots that the ND should contend for and $2^4 = 16$ real slots associated with the following contention period. In a non-contention beacon frame, this field is set to zero.

7	6	5	4	3	2	1	0
Virtual Slots				Real Slots			

Contention/uplink slot size: When number of contention slots is not zero, this field represents the size of each contention slot in multiples of 125 μ sec. A value of 0x04 means that each contention slot = $4 \times 125 \mu$ sec = 500 μ sec in length. When number of

contention slots is zero, this field represent the size of each uplink slot in multiple of 125 usec.

Uplink frequency ID: This field represents the frequency channel to be used for uplink access. It is a preferred mapping of a 16-bit index number to the actual frequency. This mapping is known to the AP and the ND.

Beacon period (T_{st}): This field represents the time period between the end of reception of this frame to the start of transmission of the next beacon frame. NDs that are not expecting to receive any data frames or do not having any frames to send, can "sleep" during for this period of time. This field is represents time in the multiples of 1 millisecond.

Number of addresses (N_a): This is the number of addresses in the list of MAC addresses to follow (see MAC address list).

MAC address list: All the registered clients with control bits properly set are included in the list. The broadcast address and the multicast addresses may also be appended at the end of the list. The control bits in the MAC address will indicate if the client is included in the uplink list, downlink list, neither or both. For every client included in the uplink list, the client preferably notes the uplink slot size, the number of packets the client scheduled to send and the accumulated number of uplink packets (T field of the control bits) preceding the client's own MAC address. The client preferably uses this information to compute the time-slot in which the client is scheduled to send the packets. Note that the time computed may exceed the beacon period. For every client included in the downlink list, the client preferably turns on the client's receiver for the period indicated by the beacon period.

Poll Beacon Frame (Downlink only)

The poll beacon frame is a special type of beacon frame used to poll the ND for the number of pending network data packets to be sent on the uplink channel. This frame shall divide the time that follows into equal-timed slots in which all registered clients can send their poll responses in an orderly manner. Each client is entitled a slot and each

poll response SHOULD indicate the number of network data packets pending uplink transmission. Clients that do not have any packets to send preferably also indicate so in the poll response. The AP uses this information to schedule the client's for uplink data transmission.

Upon receiving this beacon (identified by the type field 0x00FE), all clients preferably note the size of the poll response slot and the position of their MAC address in the MAC address list. The client preferably uses this information to compute the time slot in which it is scheduled to send its poll response.

The ND preferably verifies the AP address field to ensure that the ND did not receive the poll frame from a neighbouring cell.

Format:

Broadcast Address	AP address	Type = 0x00FE	Length	Version numbers	Contention ID	Number of cont. slots	Poll Response slot size
4	4	2	2	4	2	1	1

Uplink freqID	Beacon period(T_{st})	No. of addresses (N_a)	MAC address List	CRC
2	2	2	$4 \times N_a$	2

Fields:

Broadcast address: Same as beacon frame

Type: Set to 0x00FE.

Version numbers: Same as beacon frame.

Contention ID: Set to 0.

Number of contention slots: Set to 0.

Poll response slot size: This field represents the size of each poll response slot in multiples of 125 μ sec. A value of 0x04 means that each contention slot = $4 \times 125 \mu$ sec = 500 μ sec in length.

Uplink frequency ID: Same as beacon frame.

Beacon period (T_{st}): Same as beacon frame.

Number of addresses (N_a): This is the number of addresses in the list of MAC addresses to follow (see MAC address list).

MAC address list: All the registered clients with control bits properly set are included in the list. The broadcast address and the multicast addresses may also be appended at the end of the list. The control bits in the MAC address indicate if the terminal is included in the uplink list, downlink list, neither or both. For poll beacon frame, no client preferably is included in the uplink list. The reason is that uplink communication channel is used to send poll responses. All registered clients that receive this frame correctly preferably note the size of the poll response slot and the position of their MAC address in the list. The client preferably uses this information to compute the time-slot in which the client is scheduled to send the poll response. Note that the time computed may exceed the beacon period. As in beacon frame, every client included in downlink list preferably turns on the client's receiver for the period indicated by the beacon period.

Poll Response Frame (Uplink only)

This frame is used by registered NDs to send poll response. The frame preferably is only after a poll beacon frame.

Format:

AP Address	ND Address	Type PRP	Packet	CRC
4	4	2	2	2

Fields:

AP address: Registered NDs obtain this from the poll beacon frame.

ND address: Mac address of the terminal sending this frame.

Packet: Number of packets pending uplink transmission.

Type: PRP is set to 0x00E0.

Registration Request Frame (Uplink only)

This frame is used by unregistered NDs to register with the AP. The frame should only be sent during a contention slot.

Format:

AP Address	ND Address	Type RRP	CRC
4	4	2	2

Fields:

AP address: Unregistered NDs obtain this from the contention beacon frame.

ND address: This field is generated by the ND from the contention slot number and the corresponding contention ID of the contention period used to send this frame. The AP preferably verifies that this field is correct before accepting the registration.

Type: RRP is set to 0x00f0.

De-Registration Request Frame (Uplink only)

This frame is used by registered NDs to de-register from the AP. The frame should only be sent when polled by the AP.

Format:

AP Address	ND Address	Type RRP	CRC
4	4	2	2

Fields:

Type: RRP is set to 0x00f1.

Registration Mechanism

NDs that registers with an AP have to first listen for the contention beacon. The contention beacon contains the AP MAC address (this will be the destination address of any frame transmitted by the ND), uplink transmission frequency channel (adjacent classroom cells use separate RF frequencies to avoid interference), the contention ID, virtual and real slot numbers and the contention slot duration. The contention ID is incremented in every contention beacon.

On receiving a contention beacon, NDs randomly select a number between 0 and 255 (for e.g. the number is RW). Take RW and mask off VS-1 where VS is the number of virtual slots advertised in the contention beacon. This number is the number of real contention slots that the ND must skip (over 1 or more contention periods) before the ND can send the registration request frame. When the ND receives the contention beacon in which the ND can send the registration request frame, the ND creates the MAC address from corresponding contention ID and real slot number of that contention period. The registration request frame contains this MAC address in its source address field. When the AP successfully receives the Registration Request frame, the AP puts the ND on the polling list if the address does not already exist in the registered ND list.

There is a chance, however small, that an address already registered in the list is generated by this process. So, when the ND sends the registration request, the ND checks if the MAC address selected already exists in the list. If the address already exists, the registration is certain to fail, so the ND must attempt registration again in the next contention period.

The registration could fail if the frame collides or if received with bad CRC. In either case, the AP does not receive the RR frame. NDs must check the list of registered NDs in the next beacon to see if the NDs registered successfully. If the NDs failed to do so, the NDs must repeat the registration process.

In Fig. 6, it is assumed that the unregistered ND has just received the NDs first contention beacon. This contention beacon has the following parameters (relevant ones described):

CID = contention ID = 0x2713

RS = real slots = $8 = 2^3$

VS = virtual slots = $32 = 2^5$

(Number of contention slots field is therefore = 0x0503)

A more complicated scenario where the ND must wait for more than one contention period that have different values of VS is described. This scenario is also much more general.

Firstly, the ND receives first contention beacon with following parameters:

CID = contention ID = 0x2713

RS = real slots = 8

VS = virtual slots = 32

Secondly, the ND generates RW (between 0 and VS-1) = 0x15. Set WS = 0.

Thirdly, the ND waits off this contention period because $(RW - WS) = 0x15 > RS$.

ND sets $WS = WS + RS = 8$.

Fourthly, the ND receives another contention beacon with following parameters:

CID = contention ID = 0x2714

RS = real slots = 8

VS = virtual slots = 32

Then, the ND waits off this contention period because $(RW - WS) = 0x0d > RS$.

ND sets $WS = WS + RS = 16$.

Next, the ND receives another contention beacon with following parameters:

CID = contention ID = 0x2715

RS = real slots = $8 = 2^3$

VS = virtual slots = $8 = 2^3$

(Number of contention slots field is therefore = 0x0303)

Further, the ND notes now that $(RW - WS) = 0x05 \leq RS$.

ND sends the ND's registration request frame in the 6th contention slot. The ND uses source MAC address 0x00052715.

Note that the ND must always generate a new random number after the ND has sent out a registration request frame and found that the ND failed to register with the AP.

Polling Mechanism

The NDs acquire access to the shared uplink channel by responding to poll beacon frame. The AP sends poll beacon frames to the NDs and allocates time-slots for them to send poll response frames. Each client indicates in the client's poll response frame how many packets are pending uplink transmission. The AP gathers this information and uses the information to schedule uplink transmission.

It is the responsibility of the AP to provide fair access to the registered NDs. The scheduling mechanism is implementation dependent and it is up to the AP to determine the method of scheduling.

Power Saving Feature

As the NDs will be battery-powered, the protocol has a feature to enable power saving. The beacon frame provides the power saving feature. This frame contains list of all the registered NDs and also indicates which ND should expect at least one poll or data frame within the beacon period mentioned in the beacon frame. The NDs that do not expect any poll or data frame can go to sleep during the beacon period.

State Transition Tables

The state transition tables for the AP and ND is provided. These state transition tables are merely used to aid the understanding of the protocol.

Access Point

The state transition table for the AP only documents the states, actions and events relevant to understanding the protocol. Specifically, the table does not include states, actions and events related to scheduling of beacon, data and poll beacon frames; transmitting a non-contention beacon frame that might contain uplink and downlink scheduling information; and transmitting a network data frame.

All the above are not included as these events do not change the state of the protocol implementation.

The acronyms for the states, actions and events are as follows:

States:

S1 = No-restrictions-on-uplink state

S2 = Uplink-registration state

S3 = Uplink-poll state

Actions:

A1 = start timer $T1 = T_p$

A2 = start timer $T1 = T_{cp}$

Events:

E1 = transmit CB

E2 = transmit poll beacon frame

E3 = receive valid frame

E4 = timer T1 expired and uplink signal absent

The table shows the actions/next state transitions in each cell. Where there is no relevant action taken, then action A0 is used. Where events are not possible to take place during certain states, the symbol ILL is used.

States/Events	E1	E2	E3	E4
S1	A2/S2	A1/S3	A0/S1	ILL
S2	ILL	ILL	A0/S2	A0/S1
S3	ILL	ILL	A0/S3	A0/S1

Network Device

As in the case of the AP, the state transition table only documents the relevant states, actions and events. The acronyms for the states, actions and events of the network device are as follows:

States:

S1 = Unregistered state, MAC engine disabled

S2 = Unregistered state, MAC engine enabled

S3 = Pending-registration state

S4 = Registered state, MAC engine enabled

S5 = Registered state, MAC engine disabled

Actions:

A1 = prepare to transmit registration request frame

A2 = signal upper layer that ND is registered

A3 = pass data frame to upper layer

A4 = signal upper layer that ND is not registered

A5 = transmit data frame(s) in computed time slot(s).

A6 = transmit de-registration request frame

A7 = transmit poll response frame in computed time slot

Events:

E1 = received beacon (ND in registered list)

E2 = received compatible version non-contention beacon (ND not in registered list)

E3 = received compatible version contention beacon (ND not in registered list)

E4 = received poll beacon frame

E5 = received data frame

E6 = received beacon (ND in uplink list)

E6 = received enable engine request from host

E7 = received disable engine request from host

The table below shows the actions/next state transitions in each cell. Where there is no relevant action taken, then action A0 is used. Where events are not possible to take place during certain states, the symbol ILL is used.

States/Events	E1	E2	E3	E4	E5	E6	E7	E8
S1	ILL	A0/S1	A0/S1	ILL	ILL	ILL	A0/S2	A0/S1
S2	ILL	A0/S2	A1/S3*	ILL	ILL	ILL	A0/S2	A0/S1
S3	A2/S4	A0/S2	A0/S2	A0/S3	A0/S3	ILL	A0/S3	A0/S5**
S4	A0/S4	A4/S2	A4/S2	A7/S4	A3/S4	A5/S4	A2/S4	A0/S5
S5	A0/S5	A0/S1	A0/S1	A6/S5	A0/S5	A0/S5	A0/S4	A0/S5

*The transition to S3 only occurs AFTER the transmission of the registration request frame.

** If receive MAC disable command, then assume in registered state until beacon indicates otherwise

MAC Interface Requirements

The essential protocol interface requirements for upper layer software to interface with the MAC layer implementation is provided hereinafter.

Access Point MAC Interface: the interface at the AP must implement the following functionality:

- Reset the MAC engine
- Query version information
- Control the uplink frequency
- Receive network data frames from upper layer
- Transmit network data frames to upper layer
- Assign AP MAC address
- Remove a ND from the registered list

Network device MAC Interface : the interface at the ND must implement the following functionality:

- Reset the MAC engine
- Query version information
- Query link status (e.g. AP present)
- ND registered (ND informs upper layer)
- ND de-registered (ND informs upper layer)
- Set and re-set multicast address to listen for

Optional (dependent on implementation):

- Protocol to allow code download into ND

The preferred embodiment of this invention utilises a frequency-hopping approach. Accordingly, using the pseudo-random code sequence approach in the uplink communications channels can provide an alternative embodiment of the invention.

In the foregoing manner, a method, a system, a transceiver of a base station and a transceiver for a client or mobile station for providing a hybrid wireless communications connection suitable for use in a LAN are disclosed. Only a small number of embodiments are disclosed. However, it will be apparent to one skilled in the art in view of this disclosure that numerous changes and/or modifications can be made without departing from the scope and spirit of the invention.

Claims

1. A method of exchanging data between network entities in a Local Area Network through wireless communications media, said method including the steps of:
transferring data from a first entity to a second entity using a first wireless medium, and from said second entity to said first entity using a second wireless medium;
and
transmitting data from said first and second entities at independent data transfer rates.
2. The method as in claim 1 said transferring step including exchanging data between said first and second entities wherein said first entity is connected to a physical-line communications portion of said Local Area Network.
3. The method as in claim 2, said transferring step further including transferring data from said first entity to said second entity using optical communications.
4. The method as in claim 2, said transferring step further including transferring data from said first entity to said second entity using Infrared optical communications.
5. The method as in claim 2, said transferring step further including transferring data from said second entity to said first entity using Radio Frequency communications.
6. The method as in claim 2, said transferring step further including exchanging data between said first and second entities wherein said second entity is a portable device.
7. The method as in claim 2, said transferring step further including exchanging data between said first and second entities wherein said first and second wireless communications media form a full-duplex wireless communications.
8. The method as in claim 2 said transmitting step including transmitting data from said first entity using Time Division Multiple Access (TDMA) and from said second



entity using Frequency Division Multiple Access-Time Division Multiple Access (FDMA-TDMA).

9. A wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion, said system including:

a first transceiver for connection with a first entity for transmission and reception of data by means of first and second wireless media, wherein said first wireless medium is used for transferring data from said first entity to a second entity and said second wireless medium is used for transferring data from said second entity to said first entity;

a connection between said first entity and said physical-line portion of said Local Area Network; and

a second transceiver for connection with a second entity for transmission and reception of data by means of said first and second wireless media.

10. The system as in claim 9, wherein a transmitter part of said first transceiver, said first wireless medium, and a receiver part of said second transceiver form an optical communications connection.

11. The system as in claim 10, wherein said optical communications connection is an Infrared optical communications connection.

12. The system as in claim 9, wherein a receiver part of said first transceiver, said second wireless medium, and a transmitter part of said second transceiver form a Radio Frequency communications connection.

13. The system as in claim 9, further including a controller in each of said first and second entities for controlling access to said first and second wireless media by said first and second entities.

14. The system as in claim 10, wherein said optical communications connection is adapted for Time Division Multiple Access (TDMA) data transmission.



15. The system as in claim 12, wherein said Radio Frequency communications connection is adapted for Frequency Division Multiple Access-Time Division Multiple Access (FDMA-TDMA) data transmission.
16. The system as in claim 10, further including partitions for geographical segregation of said Local Area Network, said partitions impenetrable to optical transmissions of said optical communications connection.
17. A transceiver for use in a base unit of a wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion, said transceiver including:
- means for transmitting data via a first wireless medium;
 - means for receiving data via a second wireless medium;
 - means for connecting said base unit with said physical-line portion of said Local Area Network.
18. The transceiver according to claim 17, wherein said transmitting means utilizes optical communications.
19. The transceiver according to claim 18, wherein said optical communications are. Infrared optical communications.
20. The transceiver according to claim 19, wherein said transmitting means includes an array of light emitting devices.
21. The transceiver according to claim 18, wherein said transmitting means includes a diffused optical transmitter and an optical emitter.
22. The transceiver according to claim 18, wherein said optical communications is adapted for Time Division Multiple Access (TDMA) data transmission.





22. The transceiver according to claim 17, wherein said receiving means utilizes Radio Frequency communications.
23. The transceiver according to claim 22, wherein said receiving means includes a radio frequency receiver and a radio frequency antenna.
24. The transceiver according to claim 22, wherein said Radio Frequency communications is adapted for Frequency Division Multiple Access-Time Division Multiple Access (FDMA-TDMA) data transmission.
25. The transceiver according to claim 17, further including a controller for controlling access to said first and second wireless media.
26. A transceiver for use in a client or mobile unit of a wireless communications system for exchanging data between network entities in a Local Area Network having a physical-line portion, said transceiver including:
means for receiving data via a first wireless medium; and
means for transmitting data via a second wireless medium.
27. The transceiver according to claim 26, wherein said receiving means utilizes optical communications.
28. The transceiver according to claim 27, wherein said optical communications are Infrared optical communications.
29. The transceiver according to claim 28, wherein said receiving means includes an array of light detecting devices.
30. The transceiver according to claim 27, wherein said receiving means includes a diffused optical receiver and an optical detector.

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31. The transceiver according to claim 27, wherein said optical communications is adapted for Time Division Multiple Access (TDMA) data transmission.
32. The transceiver according to claim 26, wherein said transmitting means utilizes Radio Frequency communications.
33. The transceiver according to claim 32, wherein said transmitting means includes a radio frequency transmitter and a radio frequency antenna.
34. The transceiver according to claim 32, wherein said Radio Frequency communications is adapted for Frequency Division Multiple Access-Time Division Multiple Access (FDMA-TDMA) data transmission.
35. The transceiver according to claim 26, further including a controller for controlling access to said first and second wireless media.

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