Proposal to pursue a flexible modulation standard for IR

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Abstract

In this submission we propose a flexible standard for the IR modulation scheme to accommodate different user requirements and future technology progress. The modulation schemes considered are PPM which may provide more implementation flexibility in speed adaptation and Differential Phase shift keying or Frequency shift keying for colocated multinetwork applications such as Ad-Hoc.

Introduction

This memorandum is related to the present activities of the IR PHY (Infrared Physical Layer) working group within the IEEE 802.11 committee. Among other items, this group evaluates different modulation schemes.

Here, it is argued that a **flexible standard** for the modulation scheme is required since no particular scheme will be able to accommodate the various user needs and scenarios; a similar view was put forward in [1] for wireless systems in general. Furthermore, a too rigid standard may prevent that future products can fully benefit from advances made in component and VLSI technology and it may quickly become obsolete; significant technological advances are possible within a relatively short time, e.g. improved bandwidth of Light-Emitting Diodes (LEDs).

In principle, there is a need for a coordinated and comprehensive comparison of candidate modulation schemes (standard, new and hybrid schemes) which reflects the various user needs and is based on a defined set of criteria. Since the results of such an extensive study are not available at this time, it is not possible to make a specific proposal based on solid technical evidence for any particular scheme; however, a more general, basic assessment can be made today. The following is meant to suggest a way as to how such a flexible standard might be organized according to the various user needs and which candidate modulation schemes should be considered in each category.

Reasons for a Flexible Modulation Standard

Generally, the various requirements for a wireless system from a user's viewpoint [1] together with those of the product developers establish a conflict in the case that a single, rigid standard is chosen which is trying to accommodate all of these requirements. Such a standard will fail to serve its purpose; at best, it will suit a very limited set of requirements and represent a poor compromise for the others. This view is also applicable to the more specific problem of establishing a standard for the modulation scheme used in IR wireless links (physical level). As a further requirement, one should also consider the fact that users expect to benefit almost immediately from the most recent technological advances. The following list (not necessarily complete) provides a set of requirements, demands, criteria and concerns which reflect the various, conflicting interests of the user community and product developers of IR wireless systems:

- Usage scenarios (topologies)
  - Peer-to-peer communication
  - Adhoc / standalone networks
  - Access to wired networks (via access point)
  - Desktop resource sharing (printer, plotter, etc.)
  - Intelligent docking of mobile and portable terminals
  - Roaming between sites (cells)
- Transmission and traffic modes
  - Simplex mode only
  - Duplex mode required
  - Simplex or duplex channel with superimposed (low-rate) side channel
  - One network operating on a given site (single channel)
  - Several, ***independent*** networks operate simultaneously on same site (multi-channel capability)
  - IR system must be compatible with existing RF-WLAN (data rate, protocols)
- Propagation modes of IR light
  - Strictly diffused IR light (no line-of-sight assumed)
  - Tilted transceivers are possible (e.g. pointed at center of ceiling)
  - Aimed transceivers (line-of-sight, long distance)
  - Serial IR-interface for docking applications (SIR, short distance)
- Data rate, distance coverage, connection reliability and environment.
  - Need for highest possible data rate, distance coverage and connection reliability
  - Need for largest possible coverage, data rate is of secondary importance
  - Reliability of connection and coverage are more important than data rate
  - Direct sunlight is an issue / is not an issue
  - Fading effects at high data rates may become a problem (multipath delay spread)

- Technological issues, cost, power requirements and power control
  - Light source: LEDs vs. laser diodes (cost, power, speed)
  - User should benefit from technological advances without delay (e.g. increased band-width of critical components such as LEDs)
  - Technological advances should not necessitate a new standard to pass the benefits to the users
  - IR systems must be available at a substantially lower cost than comparable RF systems
  - Presently high costs for components and circuits should not influence the standard selection process too strongly - costs are likely to drop in the future
  - Advanced and more complex schemes offering improved performance with respect to connection reliability, distance coverage or capacity should not be ruled out from the standard because of presently high implementation costs
  - The fact that today certain schemes demand excessive power requirements (important for portable platforms) should not eliminate these schemes from the standard based on this reason alone
  - Transmitter output power should be controlled (power management)
  - Component life expectancy may be a problem (e.g. LEDs)

The listed items will influence, directly or indirectly, the definition of any modulation standard. The following proposal for a flexible standard does not claim to accommodate optimally all of the listed requirements. Rather, it solves primarily the important problem of accommodating the ***two major user requirements which are in strong conflict with each other*** if a single modulation scheme would have to be defined for a standard:

1. Need for highest possible data rate, distance coverage and connection reliability,

2. Several, ***independent*** networks must operate simultaneously on same site.

Proposal for a Flexible Modulation Standard

It is assumed that for any given technology, the available modulation bandwidth, $\mathbf{B}_m$, is a finite quantity (e.g. depending on the driver circuit and degree of modulation, $\mathbf{B}_m$, is limited to 10 - 25 MHz with current LEDs. With this fundamental constraint, no single class of modulation schemes can optimally satisfy requirements 1 and 2. Since both of these requirements are equally justified from a user's point of view, it is proposed that the IR modulation standard is defined to be *flexible* in the sense that it recognizes these needs by providing for ***two classes of modulation schemes*** where each class optimally (or nearly so) accommodates one of the requirements:

- Class 1: Power-limited modulation schemes where a single channel makes full use of the available modulation bandwidth $\mathbf{B}_m$, (requirement 1).

- Class 2: Bandwidth-limited modulation schemes where a single channel uses only a fractional segment of , say , such that up to **k**, channels operating independently can coexist (requirement 2).

A viable candidate scheme in Class 1 is ***Pulse-Position Modulation (PPM)*** since it allows exploitation of the transmitter's ***peak-power*** rating.

Candidate schemes in Class 2 are (binary) ***Frequency-Shift-Keying (FSK)*** and (differential) ***Phase-Shift-Keying (PSK)***. While PSK may be preferable over FSK because of both better performance and bandwidth efficiency [2] (p. 415), there are other bandwidth-efficient modulation schemes in this class which could be suitable for IR applications. The schemes in this class are also limited by the transmitter's ***average-power*** rating since they transmit continuously with essentially constant envelope. Thus, these schemes achieve potentially less distance coverage than those within class 1 (e.g. PPM).

BIBLIOGRAPHY

[1] F. Bauchot, *The Need for a Flexible Standard* , Document IEEE P802.11-93/108

[2] K. S. Shanmugam, Digital and Analog Communication Systems, John Wiley & Sons, New York, 1979.