Synchronized Infrared Real Time Location System

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Introduction

Real Time Location systems have become very popular in recent years. One of the first to introduce an infrared (IR) based RTLS system was Versus with a few followers. In their system, the IR tag is equipped with an IR TX module that transmits its ID to base-stations that are installed around the area of interest.

The main disadvantage of such a system is in its reliability. Infrared, like visible light, needs line of sight between the transmitter (TX) and receiver (RX) for robust detection or at least that has been the common wisdom. And indeed, the above systems suffer occasionally from a lack of reception by the receiver base-stations (BS).

In order to mitigate the above problems a few companies reversed the "positions" of the IR TX and RX. In the new systems the BS are transmitting IR signals with their ID to tags that are equipped with IR RX modules. Upon reception of the BS ID, the tag transmit (typically using RF or IR) their ID and the BS ID that they received. The central computer associates the received BS ID with the TAG ID and the position of the tag is displayed as the position of the IR BS. The use of the BS for IR transmission allows a much higher transmitted power. Those BS, in general, are connected to a power supply (through 110V). Clearly, such system can afford much higher transmission power than a TAG that is typically powered by a coin cell battery. As a result the reliability of the reception has substantially better.

In the new systems, the IR BS either transmits their ID (and other information) continuously) or almost continuously such that the IR receiver (that has no way of knowing when the transmissions occur) will be able to receive the IR signals anytime (or almost anytime). Such systems have the following shortcomings:

1. The BS cannot work on batteries – the ramifications are great as they have to choose between the following two approaches:
    a. Route power from an existing A/C outlet to a desired place for the IR BS operation – this approach is very costly (relative to the cost of a BS). In a typical installation routing power (or Power over Ethernet) can amount to $250 or more while the cost of the BS itself can be as low as $50. So, the cost of an installed BS can be as high as 5 times the cost of a BS
    b. Attach the BS directly to an outlet – This will mitigate the routing installation costs but will, in almost all cases, compromise the system performance. For example, most power outlets are installed at the bottom of walls. Not only that such BS are susceptible to being blocked by almost anything put in front of them, they need to cover twice the range that a ceiling mount BS would have to cover (if installed in the middle of a room).

2. IR BS cannot coexist in the same physical open space – Because the IR transmissions from the BS are done unsynchronized, two BS cannot be installed in the same room. If they are installed, one should expect large "dead zones" where the IR signals from the two BS overlap. If the BS would employ short random duty cycle for transmission it will force the tags to be in a receiving state for much longer with substantially reduced battery lifetime. It is important to note that synchronizing the IR tag to the IR transmitter (base-station) transmission rate is not a solution as in many cases, the tag is outside an IR BS range (places such as corridors) that are typically not covered by the "new" IR systems. In such cases, the IR tags must open their IR receivers for longer periods of time in waiting for a possible IR transmitter to appear.

The current invention solves the above problems associated with current technology.

Details of Invention

The current invention relates to Real Time Location Systems (RTLS) and in particular to IR based RTLS systems.
In one embodiment, the system is comprised of IR base-stations (BS), TAGs and RF BS. In one embodiment of the current invention, the IR transmitter is a part of the IR BS. The BS is also equipped with an RF receiver. In another embodiment, the IR BS is equipped with an IR receiver as well.
In one embodiment of the current invention, the TAGs are equipped with IR receivers and they are also equipped with an RF receiver (the same as the IR base-station). In a second embodiment, the TAGs are also equipped with an IR transmitter for communicating with an IR BS.
The basic invention relates also to the way the system operates. In its simplest form, the system works as follows: A synchronizing RF BS transmits a beacon every specified period. The period can be either fixed or transmitted as a part of the basic information carried by the beacon. All IR BS and TAGs receive the beacon. The beacon provides a unified time of origin to all nodes in the system. After a predefined period of time from the unified time of origin, the IR transmitter transmits its ID. At the same time the IR tag opens its IR RX (receiver) to receive the IR BS. After the IR TAG received (or did not receive) the IR BS transmission it can elect to transmit its ID with the ID that it received from the IR BS. The transmission is received either by the synchronizing base-stations or dedicated RF receivers scattered around the facility. These RF receiving base-stations relay the information they receive (tag IDs and the associated IR identifying codes they receive from IR base-stations) to a central computer. The information can then be displayed or processed by other client applications. The importance of synchronization is to conserve battery power consumption on the tags. The tags sleep all the time except when they either are expected to transmit or receive signals.

In an extension of the basic approach the IR base-stations transmit in delays that may be different from each other. For example, in one embodiment all odd numbered BS transmit after one delay, while all the even ones transmit in a second delay (see figures). The advantage of the "variable" delay is in the ability for IR base-stations to coexist and

function in the same physical open space. This improves coverage and allows, for example, contiguous coverage of open spaces such as corridors.
A possible application of the system is shown in Figure 4. The synchronizing base-station (that serves also for other communication to and from the tags and the IR BS) is connected to a central server (PC). The beacons transmitted are received by all nodes (both tags as well as BS). Note that to avoid IR transmissions in the open area (corridor) the odd numbered IR base-stations transmits in a different delay than the even numbered ones. This is done to avoid dead zones in which the IR receiving node cannot receive either of the IR base-stations as they interfere with each other. Another solution to the coexistence problem is using different IR wavelength by the odd and even IR base-stations and having multiple IR receivers for the different wavelengths. It is important to note that the allocation of delays need not be only for odd and even base-stations but it can be done in many other ways. For example, having a different delay to each base-station based on its identifying number. The tradeoff becomes the number of delays vs. tag power consumption.

In order to scale the system, in one embodiment of the current invention, multiple RF synchronizing BS are scattered around the facility to be tracked. We designate one of the BS as a MASTER BS and it defines the "time of origin" through its beacon transmission. All BS that receive the MASTER RF BS beacon, transmit their own beacon in predefined time slots. In one embodiment, all RF BS transmit their beacons in relatively quick succession. For example, if we have 10 RF BS around the facility and each beacon duration is about 5 milliseconds with basic interval between beacons of 10 milliseconds, the entire beacons' period is 100 milliseconds. The basic period of the system is expected to be somewhere between 3 seconds and 45 seconds. Each beacon transmits along other information, its offset to the time of origin. Any TAG or BS that receives any beacon information knows how to time their transmission or reception regardless of what beacon there are tuned to. This is very important part of the invention as TAGs and IR BS can lock on different beacons and without locking to absolute time of origin the TAGs and BS will not transmit and receive at the same time.

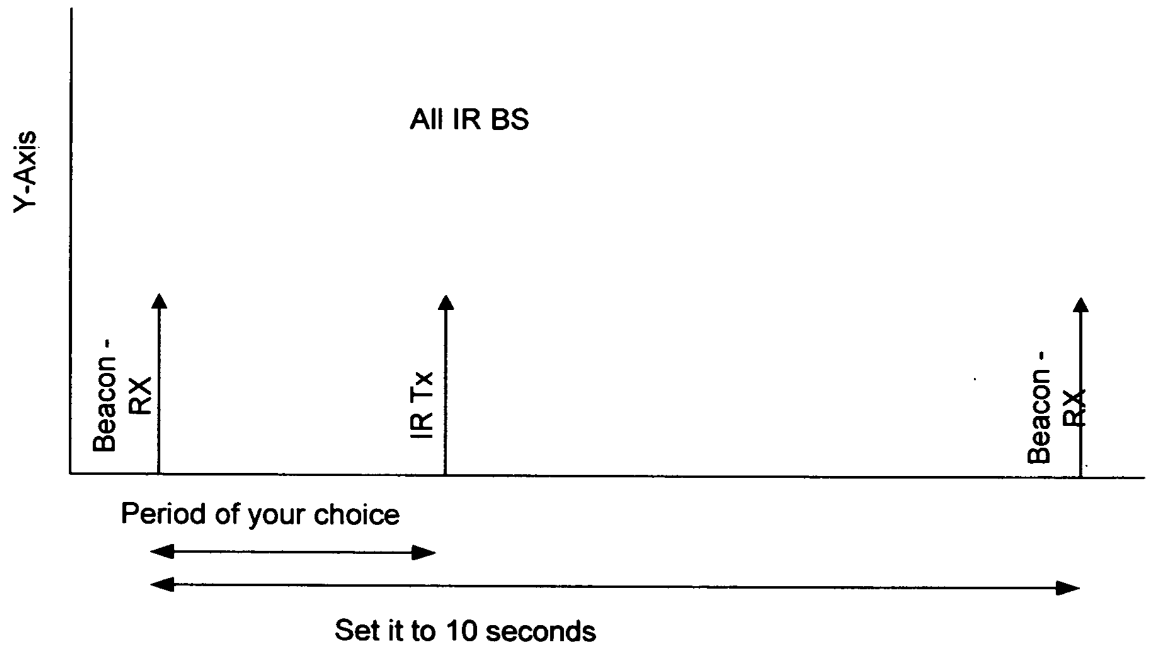
Summary

We described an invention of an RTLS system that combines infrared and RF communication systems. The improvement of the design in two main areas due to the use of synchronous signaling: (1) Use of battery operated BS that enables simple and low cost installation (2) allows coexistence of IR base-stations without causing dead regions due to overlap in coverage.

What we mainly claim:

1. IR transmitting nodes that transmits an identifying infrared code in a known delay from a synchronizing received RF beacon
2. The transmitting node in (1) with at least one receiving node (TAG) with a unique identifying code that is synchronized to the same received RF beacon.

3. The receiving IR node according to (2) with an RF transmitter to transmit its identifying code and the identifying code of the IR transmitting node it received.
4. The IR transmitting node in (1) with a delay depending on its identifying code.
5. The system in (1) with the receiving node in "sleep" mode except in prespecified delays from the beacon.
6. A plurality of synchronizing base-stations that transmit beacons, each in predetermined time slot; the beacons carrying information on their transmission time relative to a unified time of origin.
7. The IR transmitting nodes in (1) transmitting an identifying infrared code in a known delay from the unified time of origin of claim (6).
8. The IR receiving nodes in (2) transmitting an identifying infrared code in a known delay from the unified time of origin of claim (6).



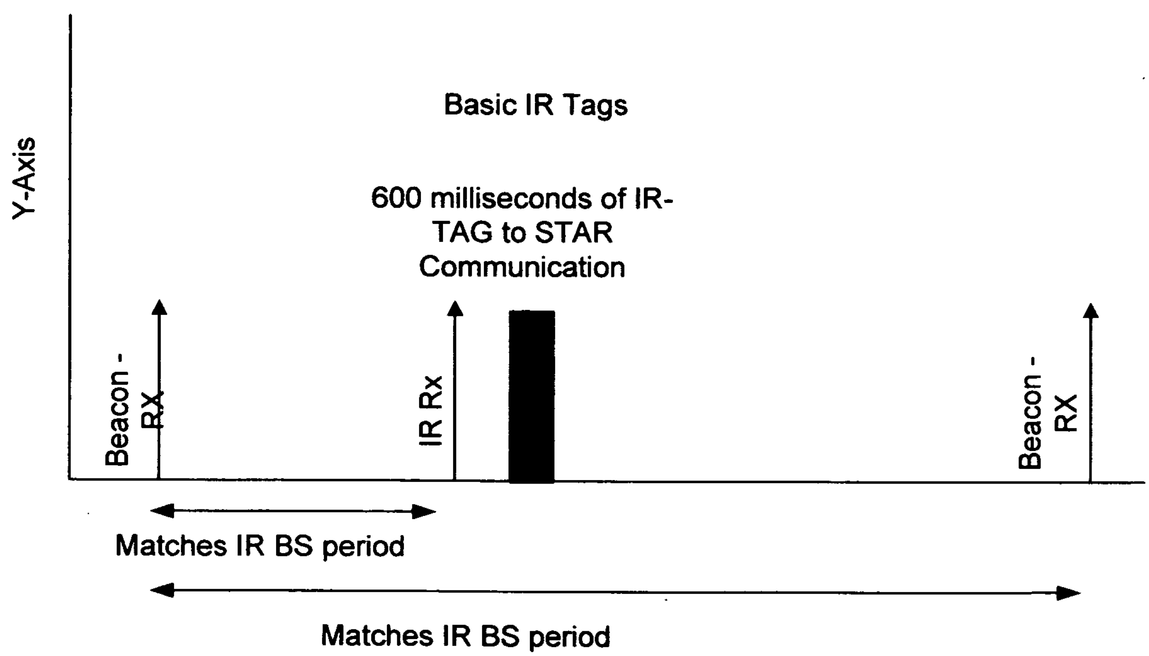


Figure (1): The basic configuration. All IR BS and all TAGs transmit and receive at the same time delay after the beacons are received.

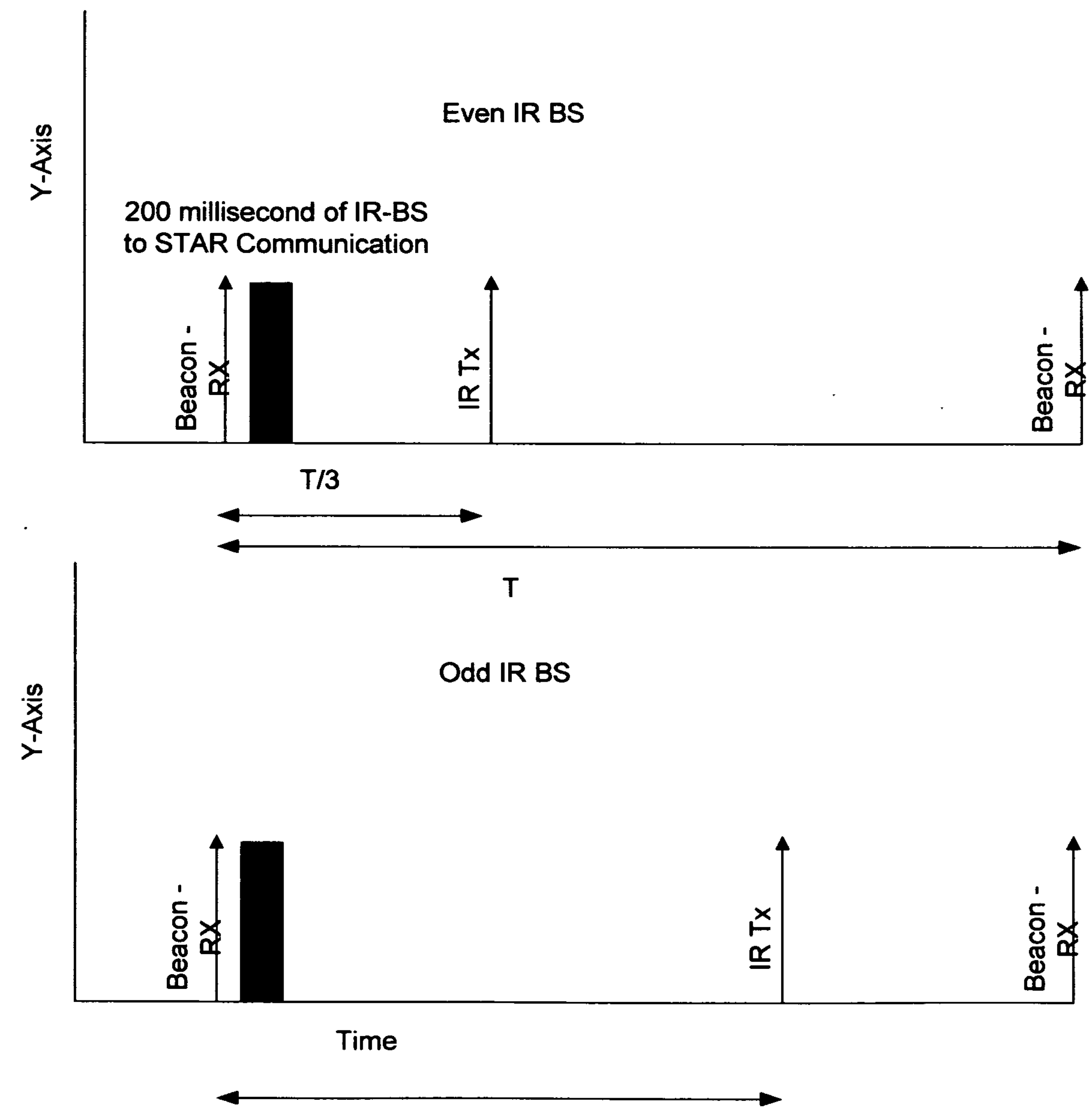
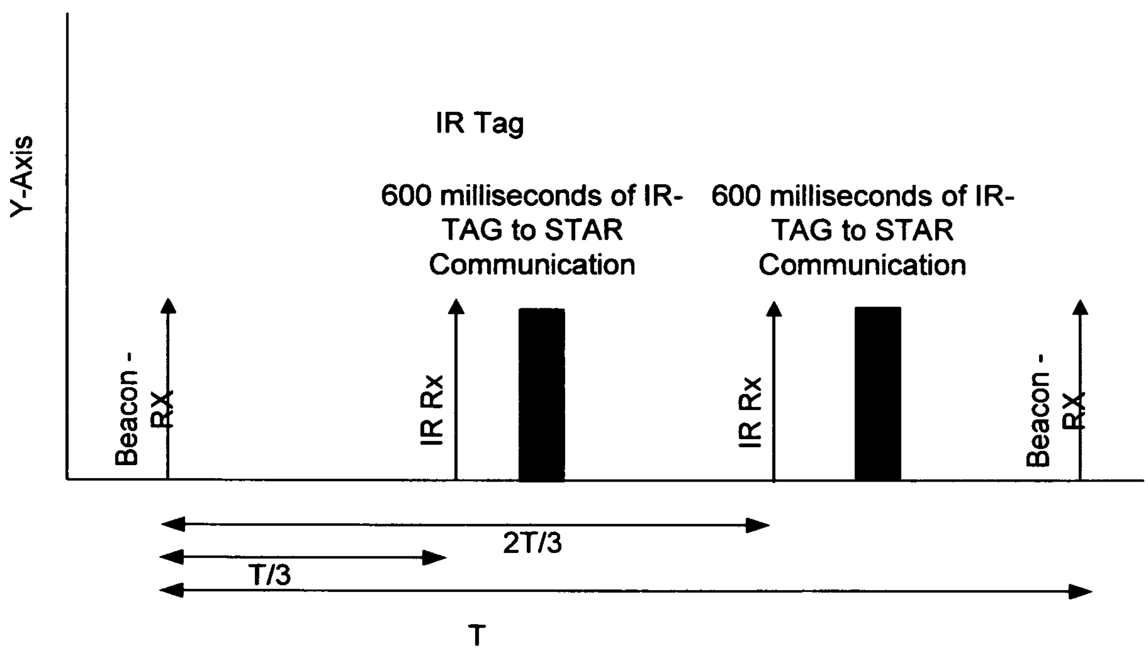


Figure (2): an example of odd and even transmissions delays of IR base-stations



Basic IR Tags

Figure (3): The IR receiving nodes (Tags) receive both odd and even IR BS without interference.

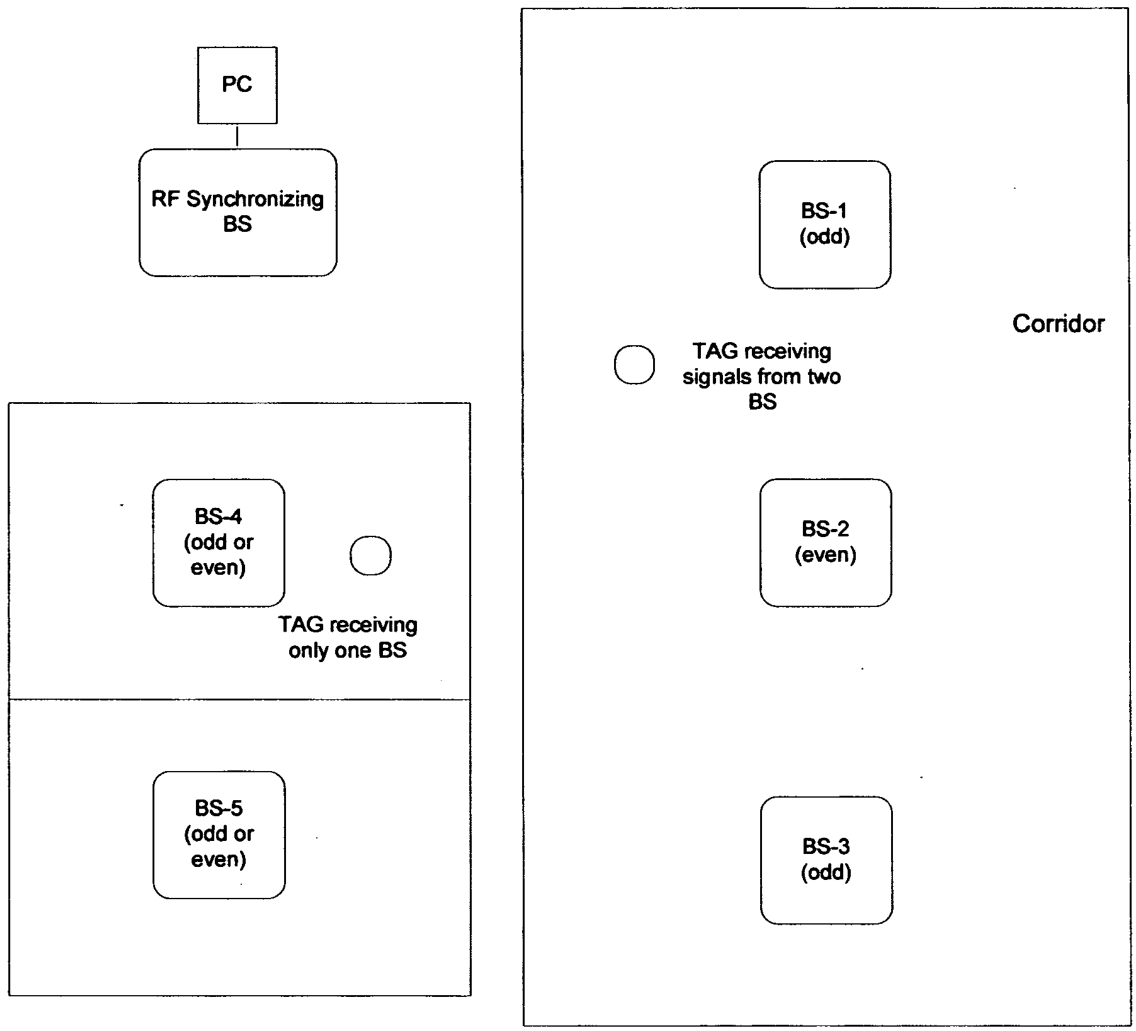


Figure (4): An embodiment that includes open spaces (BS-1, BS-2 and BS-3) as well as isolated areas (BS-4 and BS-5).