WHITE PAPER

Co-Pilot Beacons: A Solution for E911 and Location Based Services

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Executive Summary

With the increasing use of wireless phones and the continued demand for in-building coverage, quick, reliable, and accurate location of mobile devices for both public safety and location based services (LBS) is a must. Typical methods used in macro cellular handset location determination do not work adequately for in-building and DAS (Distributed Antenna System) simulcasting applications. CSI's Co-Pilot Beacon (CPB) facilitates E911 and other LBS for in-building and/or DAS-based installations of CDMA2000/1xEV-DO cellular networks. This white paper will further describe the problem, the solution, and explain how to implement the Co-Pilot Beacon in an in-building system design.

Product Overview

Pilot beacons have traditionally been used by CDMA carriers for facilitating hard hand downs between carrier frequencies, and to a lesser extent, hand downs from CDMA to analog channels. By transmitting the pilot, page, and sync channels as a "guide" for the mobile device, the chance of completing a handoff between carrier frequencies is greatly increased.

Under typical indoor conditions and outdoor DAS applications, methods for location determination, such as direct reception of GPS by the mobile device or triangulation using the signals from multiple base stations, do not meet accuracy requirements.

By properly locating CPBs, mobile devices quickly and reliably receive fixed location references that allow the network to determine a handset or mobile device's specific location. The position information can then be used to aid the GPS receiver in acquiring signals, if they are present, or it can be used directly as a position report until more accurate information becomes available. The CPB system can then provide location information to emergency personnel (within FCC mandated Phase II parameters), ensuring a timely response.

Benefits

- 100% handset compatibility with all CDMA phones
- Ability to optimize location resolution for the needs of the site by simply adjusting the number of CPBs installed
- Compatible with virtually all indoor and outdoor repeater/DAS solutions
- Offer full coverage for all of a provider's CDMA channels from a single Co-Pilot Beacon

Applications

The CSI CPB is designed to facilitate better location accuracy for CDMA in-building systems and for outdoor simulcasted DASs. An augmented system utilizing CPBs can accurately locate mobile users and provide this information to the Public Service Answering Point (PSAP), facilitating dispatch to first responders. The CPB provides an optimal solution that will meet requirements for location determination in each of the following applications:

- Airports
- Stadiums and arenas
- Hospitals
- Campus environments
- Tunnels
- Office buildings
- Manufacturing facilities
- Macro environments

Operational Description

Over the past decade, the number of indoor repeater applications and outdoor DAS implementations has increased greatly and will continue to expand. While indoor and outdoor DAS implementations have dramatically improved coverage and capacity for wireless devices, they have created holes for both navigation applications and public safety E911 calls. Of greatest concern is the ability for first responders to locate users during emergencies.

In indoor and outdoor simulcast DAS situations, the normal methods for location determination, direct reception of GPS by the mobile handset, or triangulation using the signals from multiple base stations, may not work sufficiently. Signals from a GPS system may be so weak that even if the mobile handset's GPS receiver is capable of locking on to the satellites, the acquisition time could be too long. And since indoor service is typically provided either by a single strong local cell or by using a repeater, the necessary number of signals are not available. In this situation, the triangulation method will not work. Repeaters exacerbate the problem due to inherent delays that magnify errors. By placing a pilot signal at a known PN offset, the LBS algorithm can quickly and reliably locate the mobile handset.

Architecture Overview

Standard Positioning Architecture

Figure 1 depicts an example of how a network is configured to Assist GPS (A-GPS) for LBS solutions.

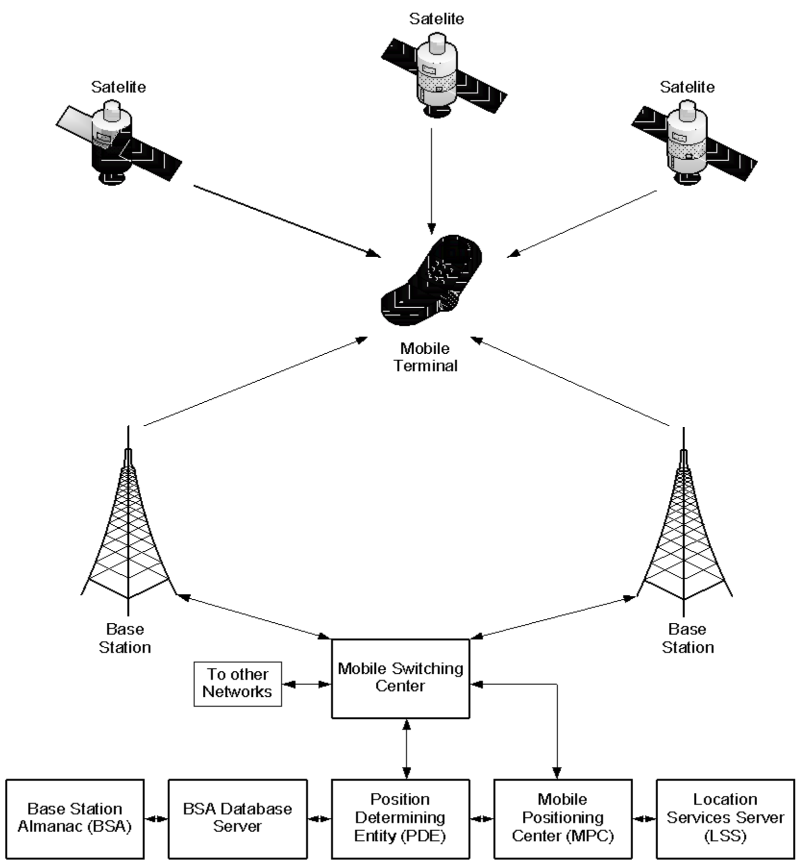


Figure1: Standard Positioning Architecture

Standard Positioning Methods

Basic Positioning Method	Description	Accuracy
Cell-ID	Obtains cell-ID based on pilot measurement; provides identity of cell only	100m to 3km, depending on location of cell
Mixed cell sector	Depends on sector size and the accuracy of timing and/or signal strength measurements	100m to 3km, depending on cell size and density
Advanced Forward Link Trilateration (AFLT)	Determining the position is solely based on cellular measurements	50m to 200m
Hybrid/ A-GPS	GPS positioning with Assisted Network measurements	30m to 200m
GPS	GPS positioning only	1m to 30m

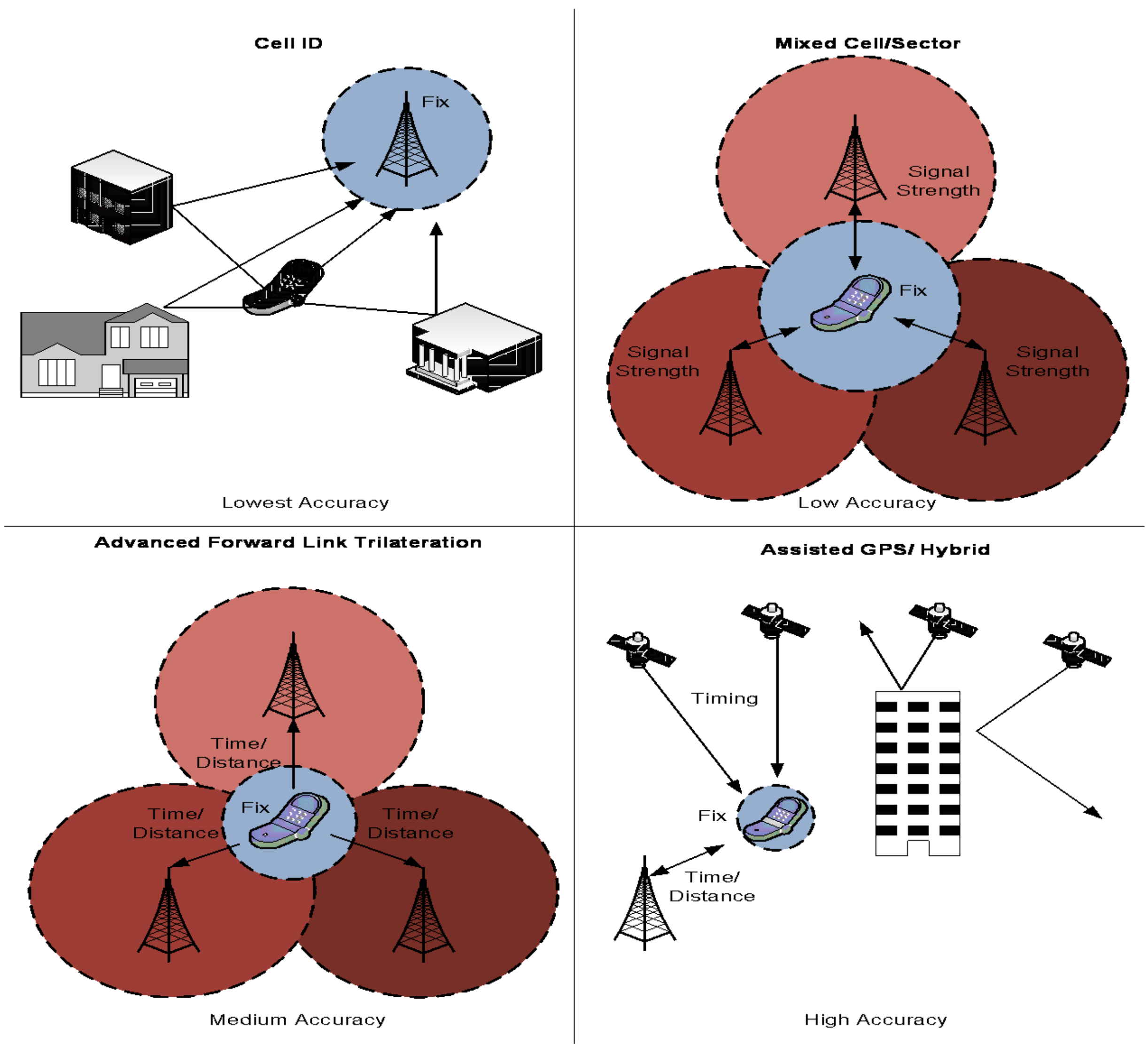


Figure 2: Standard Positioning Methods

LBS Challenges

Obstacles to meeting LBS needs are increasing with the continual growth of off-air in-building and outdoor DAS deployments throughout the country. The guidelines mandated by FCC Phase II for public safety require that, within six months of a request by a PSAP, the latitude and longitude of the caller must be provided.

The allowable errors are:

- For network-based solutions, 100 meters for 67%; 300 meters for 95%.
- For handset-assisted solutions, 50 meters for 67%; 150 meters for 95%.

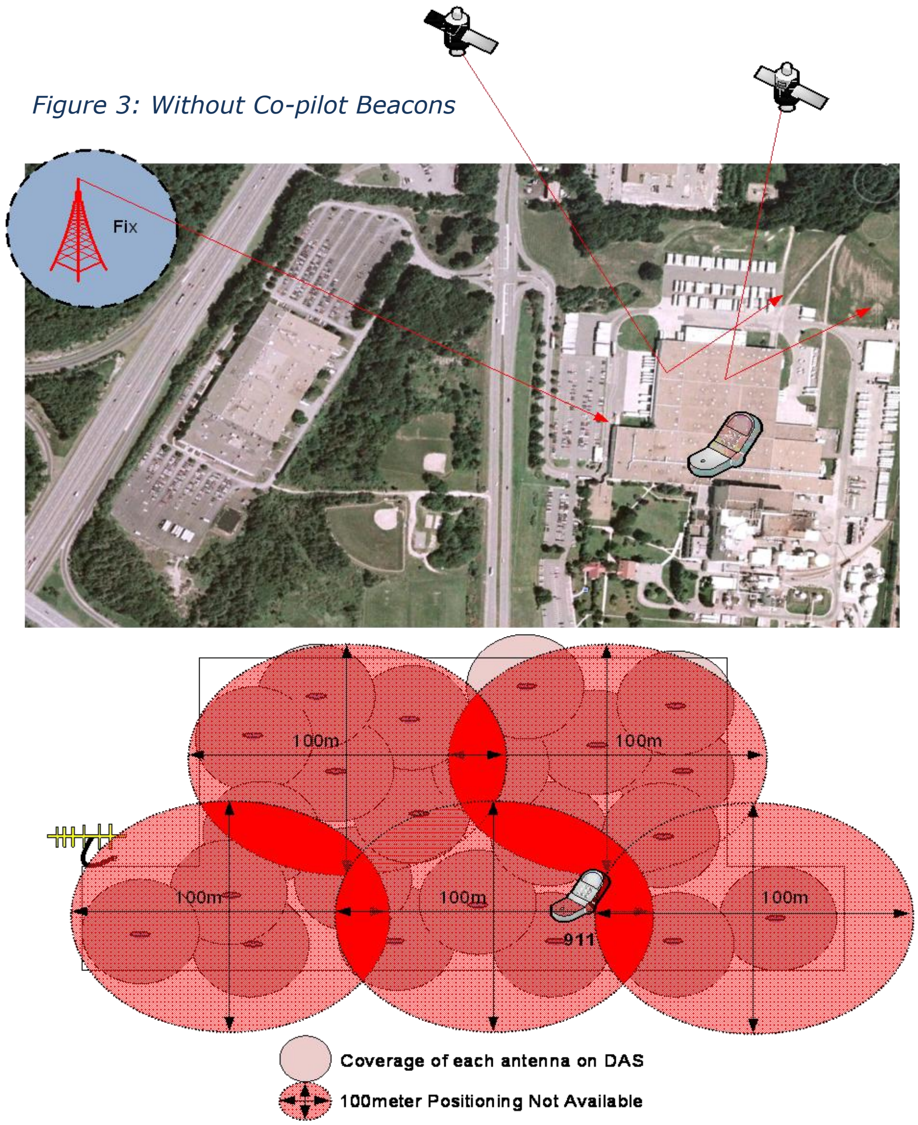


Figure 3: Without Co-pilot Beacons

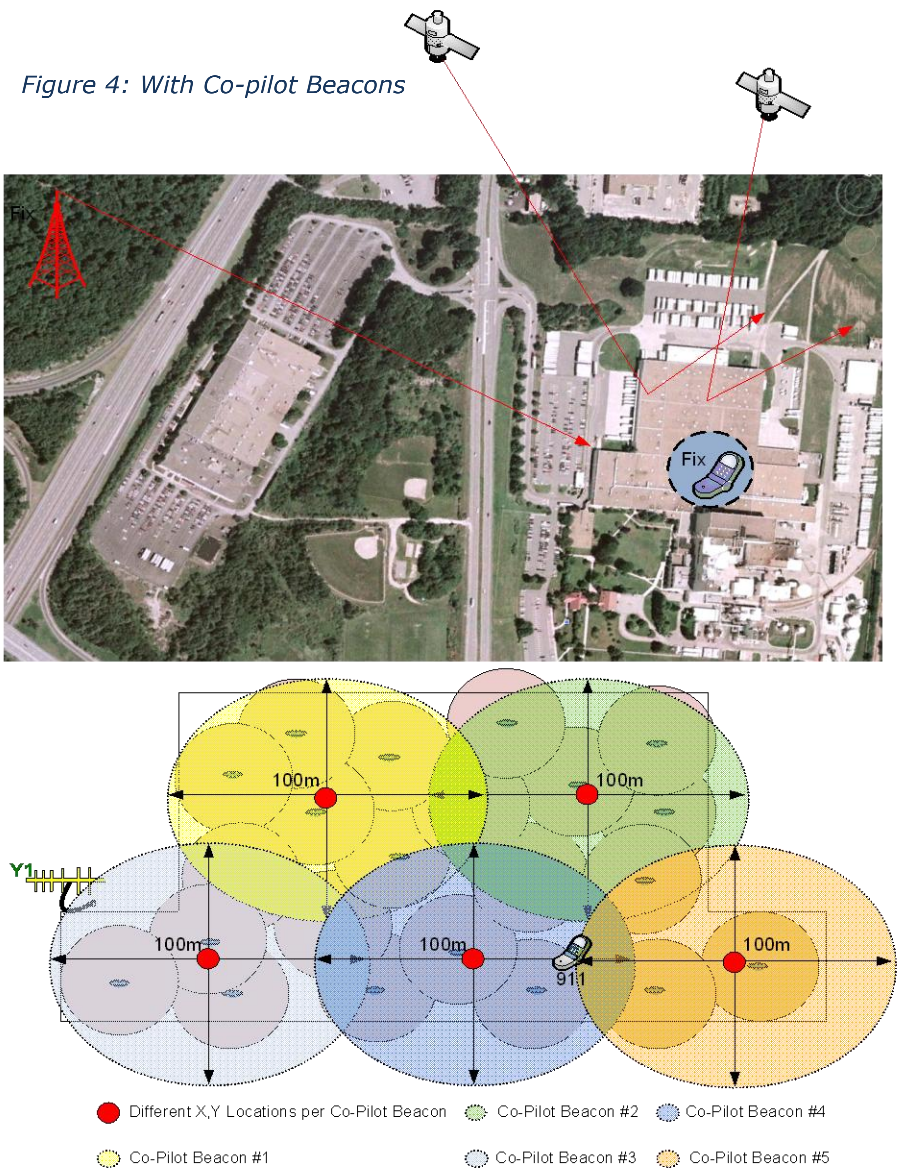
The illustration above (Figure 3) depicts an off-air fiber DAS installation. The in-building DAS receives the RF signal from a base transceiver station (BTS) site located two miles away, which is then amplified and distributed over fiber throughout the million-square-foot facility. When an E911 call is made, A-GPS is attempted but cannot be used due to insufficient satellite signal penetration into the building. Advanced Forward Link Trilateration (AFLT) would then be attempted, but again, due to lack of building penetration, the mobile device might not see the necessary number of PNs to provide timing and ranging. Mixed/cell sector would then be used to average, by signal strength measurements, but would also not work unless multiple-source signal strength measurement information is available. Without GPS, AFLT and mixed/cell sector, cell-ID is used to identify the nearest BTS site. This usually does not meet Phase II requirements.

The same scenario is shown with the augmentation of CPBs to enhance LBS performance (Figure 4). The in-building DAS receives its RF from a BTS site two miles away and is amplified and distributed over fiber throughout the same million-square-foot facility. The CPBs are summed into the fiber head-end, creating five CPB zones throughout the facility. Each CPB zone has been assigned a PN offset to broadcast with the traffic signals. A GPS antenna or antennas are located on the roof for satellite timing reference. When an E911 call is made, the method using GPS/A-GPS is tried first but cannot be used because the mobile device is not receiving timing directly from any satellites. The mobile device will then try to use AFLT. When performing the PN scan, the mobile device will receive signals from the CPBs and use these signals to provide timing and ranging. A fix is quickly provided and accurate location of mobile devices is accomplished.

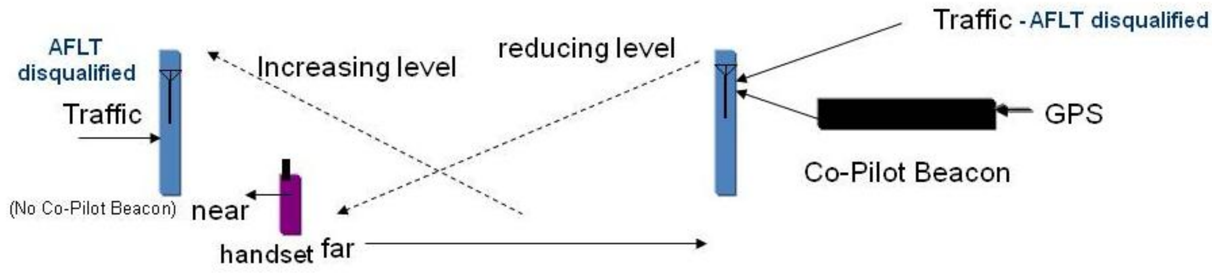
Design

Locations of pilot beacons are chosen to provide adequate co-pilot signal levels for a handset to use for ranging. CPBs are almost always transmitted with traffic signals. The signal strength of the CPB is set to the same level as the RF for the DAS (indoor or outdoor) coming from a known BTS or repeater output signal. When designing the CPB into an indoor or outdoor DAS, one must consider near/far performance (Figure 5) and eliminate any location determination holes caused by the CPB itself. (A location determination hole is a location where no CPB can be detected due to a strong nearby traffic antenna not transmitting a CPB signal.)

Figure 4: With Co-pilot Beacons

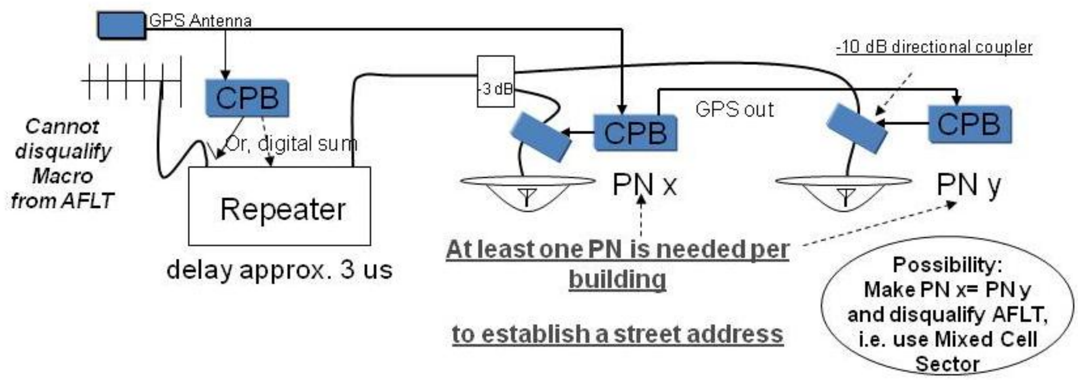


Near/Far Problem Scenario *(Figure 5)*

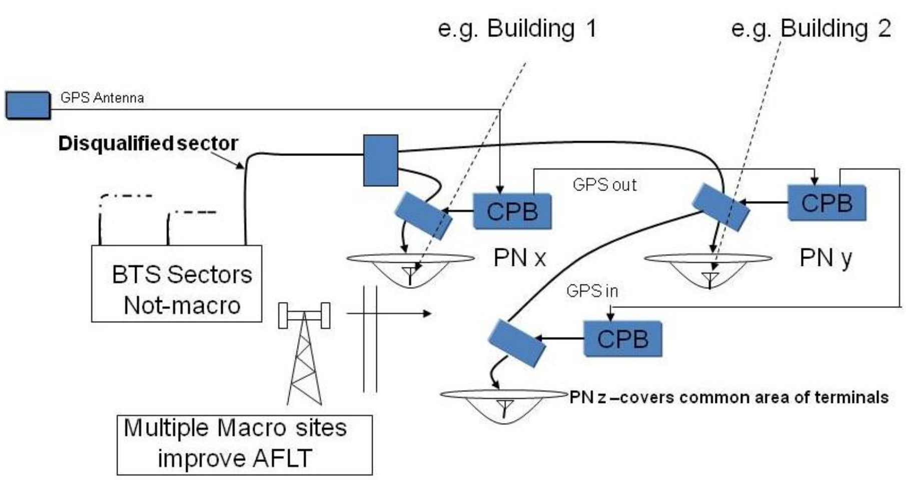


Common Deployment Scenarios

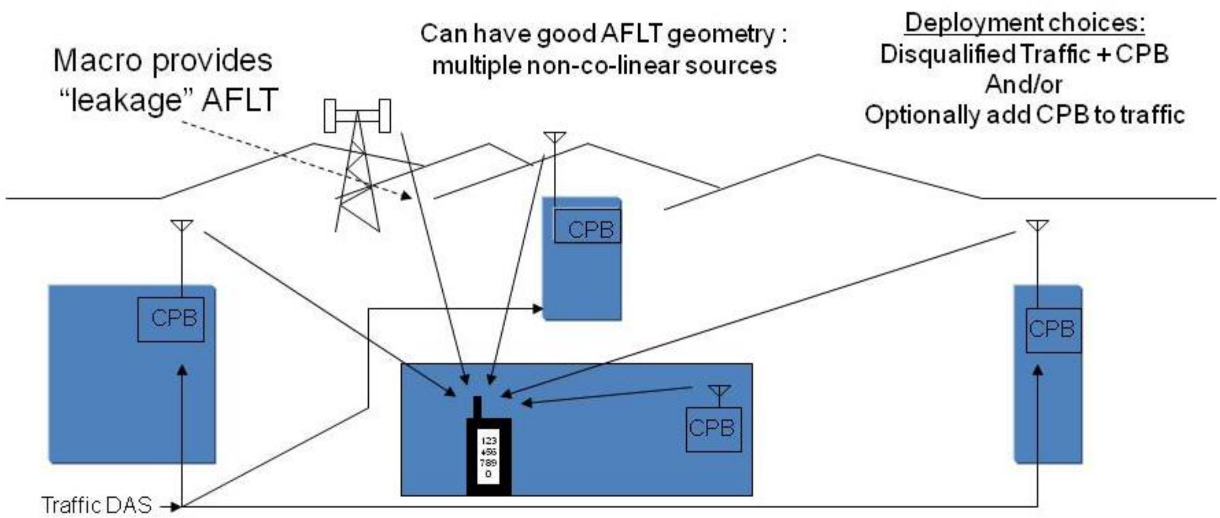
Repeater Scenario *(Indoor or outdoor solution fed from a macro site.)*



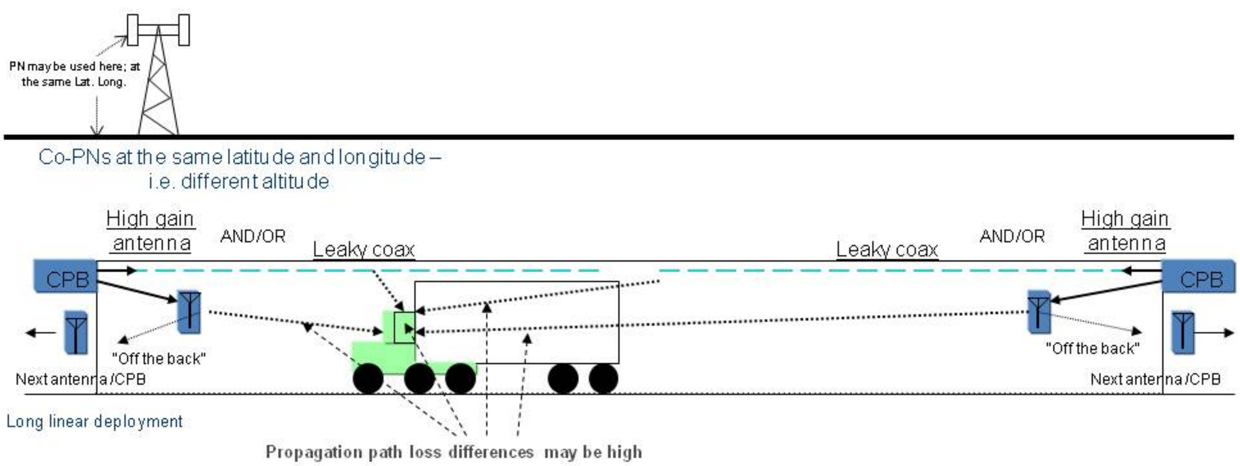
BTS Traffic Sector *(Indoor solution. Single or multiple buildings.)*



Hybrid Scenario *(Outdoor and/or outdoor-to-indoor solution.)*



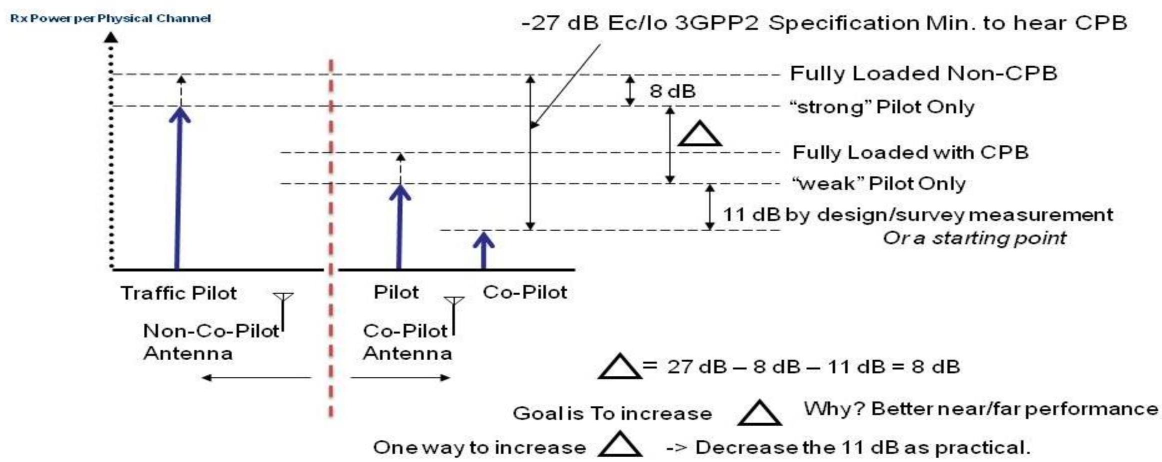
Tunnel Scenario *(Long linear deployment. Little or no macro coverage.)*



Power Levels

When a BTS is being used to supply RF to a DAS, CPB PN should typically have power set 11dB below the traffic pilot. When a repeater is being used to supply RF to a DAS, CPB PN should typically have a power level 27dB below the traffic pilot at the edge of the buildings coverage area. This will reduce CPB leakage into the macro, reducing the possibility of a mobile outdoors seeing a co-pilot. This will also reduce any possible contribution to a skewed macro fix.

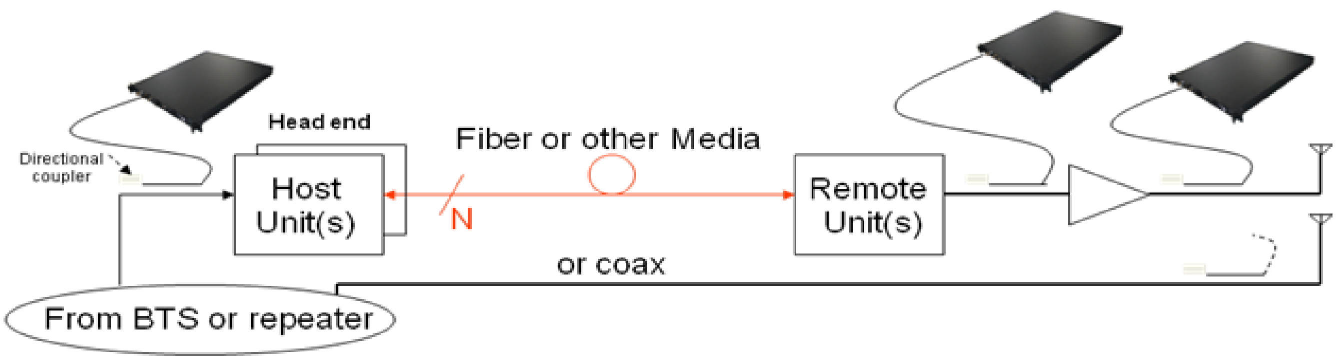
Example of Near/Far power levels



Where to Inject

Depending on the expectation required for the LBS, there are many different places where the CPB accuracy can be summed into a coax or fiber DAS. Summing may be performed with a directional coupler.

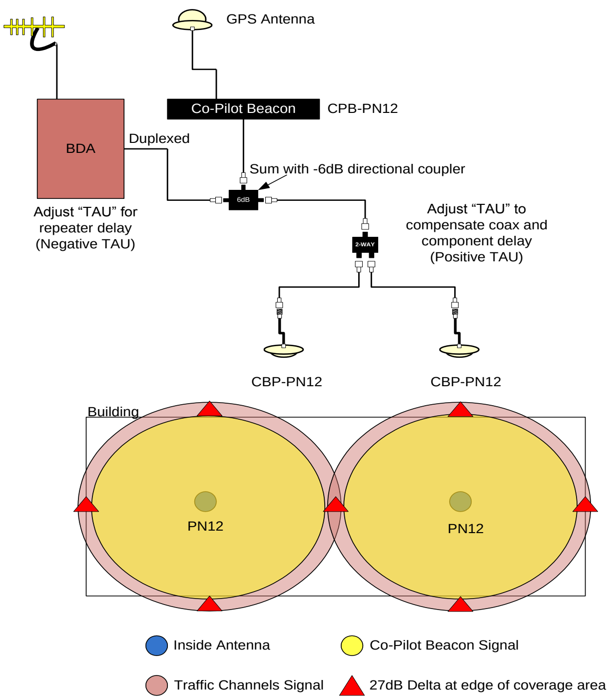
- Inject low power into a host unit
- Inject at low power before the power amp of a remote unit
- Inject high power directly into an inside antenna



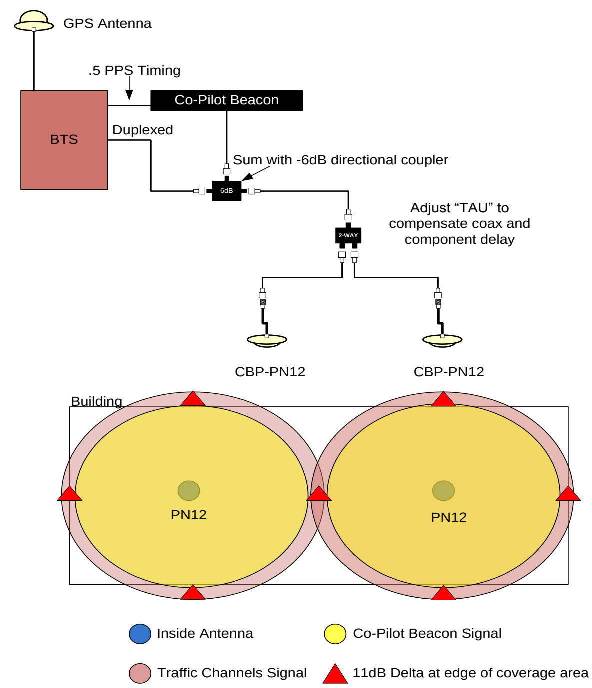
Implementation

The CPB requires a timing reference to synchronize all CPBs within the network. An external GPS receiver or external time source can be used for this. When integrating one or multiple CPBs into a DAS (indoor or outdoor), and the RF is from a BTS, an additional GPS antenna for the CPB is unnecessary. Most base stations have a .5 PPS port for timing reference that can be used for the CPB. If all the CPBs are located in the same area, the timing reference can be daisy-chained from one device to the next.

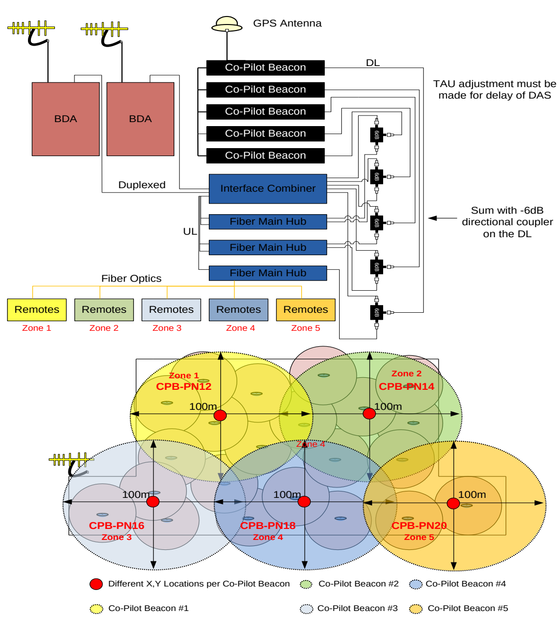
When attaching one or multiple CPBs into a DAS (indoor or outdoor), and the RF is from a repeater, a GPS antenna should be installed on the roof for the CPB. The GPS must have a clear view of the sky. The timing reference can be daisy-chained from one CPB to the next.



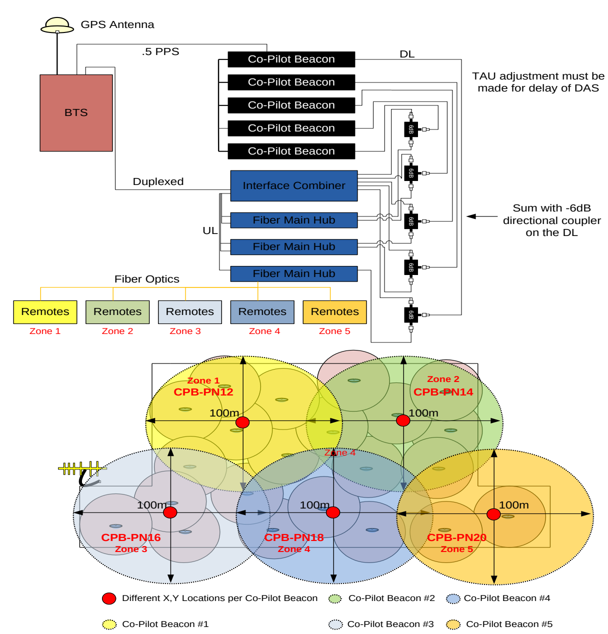
Example of coax DAS/repeater feed



Example of coax DAS/BTS feed



Example of fiber DAS/repeater feed



Example of fiber DAS/BTS feed

Conclusion

By augmenting DAS implementations with Co-Pilot Beacons the ability to accurately locate mobile devices is greatly enhanced. CDMA wireless service providers (WSPs) can utilize DASs to cost effectively expand coverage and capacity while complying with public safety needs, FCC requirements, and LBS accuracy demands.

Acronyms and Definitions

AFLT	Advanced Forward Link Trilateration
BTS	Base Transceiver Station
CDMA	Code Division (or, Domain) Multiple Access: The general term for the technology used in the CDMA2000 system as well as other systems. Also a shorthand reference to the CDMA2000 system and its derivatives such as 1xEV-DO
Chip	A single element, a "1'"or a "0", of the PN Sequence in a CDMA system. The chip rate for the CDMA2000 system is 1.2288 Mchips/second.
DAS	Distributed Antenna System
EST	Even Second Tick: In the CDMA2000 cellular system all time values are referenced to the start of the even seconds of time as indicated by GPS.
FCC	Federal Communications Commission
GPS	Global Positioning System
GUI	Graphical User Interface
IF	Intermediate Frequency
LED	Light Emitting Diode
PN	Pseudo random Number: A number chosen by some algorithm that approximates a random process. Can be short for "PN Sequence", "PN Number", or "PN Offset" when discussing the CDMA2000 system.
PN Number	In the CDMA2000 system only a subset of the possible PN Offsets are used for base station identification. Each of these allowed offsets is given a unique number from 0 to 511.
PN Offset	In the CDMA2000 system, each base station is identified by the offset in time from the EST at which the start of the Pilot PN sequence occurs. The offset is specified in terms of number of chips.
PN Sequence	A sequence of pseudo random numbers. In the CDMA2000 system, several such sequences are used.
PPS	Pulse per second: Refers to the pulse repetition rate of the timing signal used as a time reference.
RF	Radio Frequency
Tau	Timing Offset or Delay Adjustment: In the CDMA2000 system, the timing of the downlink signal must be aligned with the EST as it is transmitted from the antenna. Tau allows the timing of the internal PN sequence to be adjusted to compensate for the delays of the base station hardware so that the timing will be correct at the antenna.

About CSI

Cellular Specialties, Inc. (CSI) delivers products and services enabling anytime, anywhere wireless connectivity. The CSI Product Division specializes in the development of in-building amplifiers, repeaters, system components, and co-pilot beacons for indoor and outdoor DAS networks. CSI is the first company to introduce a digitally filtered repeater capable of passing WSP spectrum requirements, thus becoming the preferred repeater vendor for the nation's largest wireless carriers. To ensure that optimal services are provided, CSI formed the Custom Solutions Group (CSG). Since its establishment, CSG has implemented over 7,500 turnkey solutions throughout the country. CSG also holds the distinction of being the only in-building wireless service organization approved by all major wireless service providers in the United States.

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