Real Time Tracking of Optical Cabling using RFID

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Managing cable infrastructure within a data center is an important and difficult task. The ability to locate cables and, more importantly, their interconnections would be very helpful. The extremely dense packing and wide variety of connector designs makes it difficult to provide an all encompassing tracking solution. We have addressed this problem through tagging cable ends with generic RFID tags and the development of a fine grain RFID location system. This location system uses several novel designs to support industry standard cable densities of as many as 48 cables ends per 1U slot.

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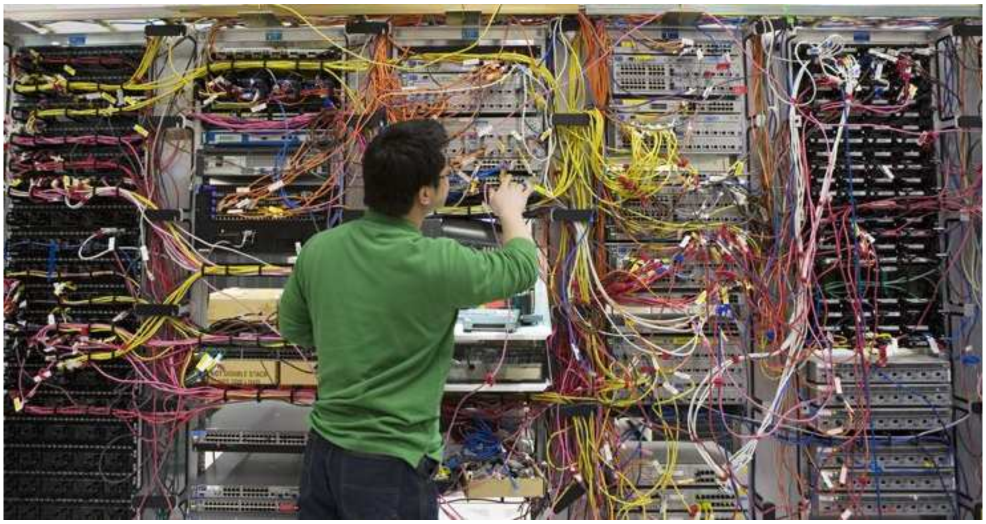
Abstract

Managing cable infrasrtucture within a data center is an important and difficult task. The ability to locate cables and, more importantly, their interconnections would be very helpful. The extremely dense packing and wide variety of connector designs makes it difficult to provide an all encompassing tracking solution. We have addressed this problem through tagging cable ends with generic RFID tags and the development of a fine grain RFID location system. This location system uses several novel designs to support industry standard cable densities of as many as 48 cables ends per 1U slot.



Problem Statement: Managing thousands of data paths in a complex data center

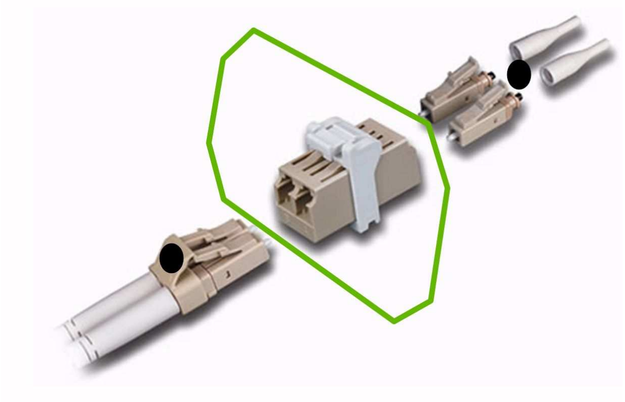
A data center may contain thousands of data paths connecting all manner of equipment. For flexibility, each data path typically consists of several physical cables. For example, a data path may consist of a first cable leading from a networking end point through one or more patch panels, followed by a second trunk cable running to another concentration point, and lastly a third cable terminating at a remote device. In a large installation, it is difficult to answer seemingly simple questions such as “How many trunk lines are still free between building A and B?” Or “Does this cable lead to the correct concentration point?” To underscore the scale of the task, consider that a single fully populated concentration point housed in a standard data center rack can support over 2000 connections comprised of 4000 cable ends. For correct operation, data center managers must be able to organize all logical data paths. To keep from drowning in a sea of wires, the managers must meticulously track the physical cabling plant as well. Given the sheer number of items, this is no easy task.

Two conditions make the task of manually tracking cables especially difficult. First, the density of cable connections is quite extreme, with just enough room to allow for manually operating the connector clip. Secondly, each connection involves two cable ends – one of which is hidden on the back side of the junction panel. Finally, the cables in a bundle look alike. The only distinguishing marks are clip-on printed or hand-written labels. Some sites have moved to bar-coded labels, which can lead to their own problems due to the difficulty of properly aiming the reader.

Our Solution: Uniquely identifying cable ends with RFID tags

By attaching an RFID tag to each cable end we are able to uniquely identify each end point. Stored in the memory of each tag is a shared number that uniquely identifies the two tags as belonging to one cable. The junction panels are replaced with low cost RFID readers capable of reporting the location of each tagged cable end. The technique offers several desirable features:

- Each cable end is uniquely identifiable.
- Tracking can be automated and real-time.
- The solution is contact-less. During reading, the cables and connections remain undisturbed.
- Tags can be applied to industry standard cables.
- The technique is easily adapted to existing cable infrastructures.
- No exposed contacts or connectors on cables, patch panels or probes.



This solution does come with challanges. There are three technical barriers, all due to the difficultly of creating suitably dense arrays of RFID readers. First, the relative proximity of the readers invites interference. Second, the high density implies small reader antennas with prohibitively small read ranges. Finally, since there are so many junction points (>2000 in a rack), the cost per reader must be very low.

The cost-per-reader challenge was largely addressed in a previous RFID solution designed to track rack-mounted assets [1]. That solution achieved low cost by sharing one set of RFID circuitry across many antennas that are closely associated in a multi-reader strip. This technology fits in very well with our cable tracking goals.

To overcome the limited read range, we needed to use larger antennas while still achieving a finer read granularity. We chose to replace the one-antenna-per-junction design with a more complex design using larger antennas. The larger size provides sufficient read range for the RF field to reach out and detect both tags in a connected pair of cables. Unfortunately, the larger reader antennas cover several junctions, leading to ambiguity as to exactly where the cable ends are. Using a pattern of overlapping antennas resolves the ambiguity. If one antenna detects tags {A, B, **X**, **Y**} while a second antenna detects {**X**, **Y**, C, D}, we can conclude that tags X and Y are in the overlapping area and are connected. Tags A, B, C & D must lie outside of the overlapping area and thus are not part of the junction.

Our current design divides up the 1U space into three regions. Each region uses two antennas oriented horizontally (rows) and four oriented vertically (columns) to cover the eight junction points. Cables at each junction point belong to the coverage zone of exactly one antenna in each orientation. Four tags might be detected by one vertical antenna, but only two of these will also be visible to a horizontal antenna. These two cable ends are located at the intersecting junction point and can be assumed to be connected together. As a side benefit of this row/column arrangement, only six antennas are needed to cover eight positions. This basic 2x4 pattern is repeated to form larger grids.

While overlapping antennas solve the range problem, they greatly exacerbate the challenge of reader interference. The biggest problem being the cross coupling between reader antennas. When energizing one antenna, some energy will be captured and re-radiated by adjacent or overlapping antennas. If sufficient energy is cross coupled, tags outside of the intended read area will respond. The remedy is to make multiple readings with varying power levels. Tags within the nominal coverage zone of an antenna, are detected at lower power levels than more distant tags. Because of power losses in the cross coupling, transitive detection of tags requires relatively higher power levels. By comparing the power level used for each detection of a tag, the cross coupling situations are easily distinguished.

Technical improvements we have developed, we have been able to significantly extend the read range. The industry standard tags can now be attached to convenient points on the cable end out of the way of the juction.

With the current design, fully inserted cables are always successfully read. There is still some room for optimization in the design. Extra read range would allow for greater choices in tags and tag mountings.

The initial focus on the optical cable infrastructure was largely influenced a lack of existing solutions and the relatively high cost of optical components. The cost of our solution is small when compared to the cost of optical cables and their specialized connectors. The solution should be adaptable to any cable type. The concept could be extended to copper cables bringing with it more comprehensive cable systems management.

So far we have constructed several working prototypes. We are working with internal organizations to integrate this product idea into HP's existing hardware and software offerings. Some preliminary work has been done to integrate with the Perigrine Cable module. Initial interest from end customers has been high.

RFID in a nutshell

RFID tags are, in essence, tiny computers that get their power and communications from an RF field generated by a reader. Once the tag receives sufficient power from the field, the tag acts like a smart two-way radio. It can receive digital queries and respond. The most common query is to retrieve the unique 64bit ID that is burned into the silicon of the RFID tag. More advanced tags have local re-writable memory. Some tags can even perform encryption or physical measurements such as temperature or pressure.

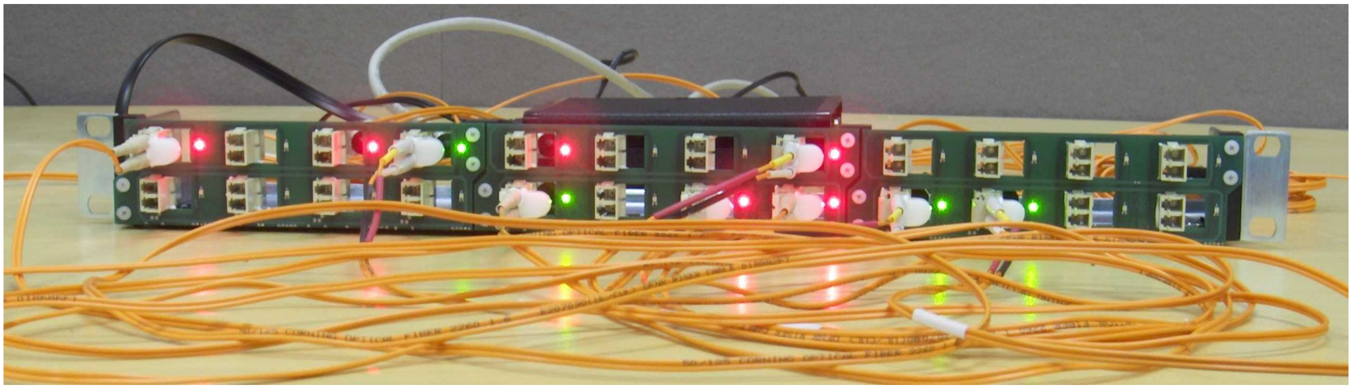
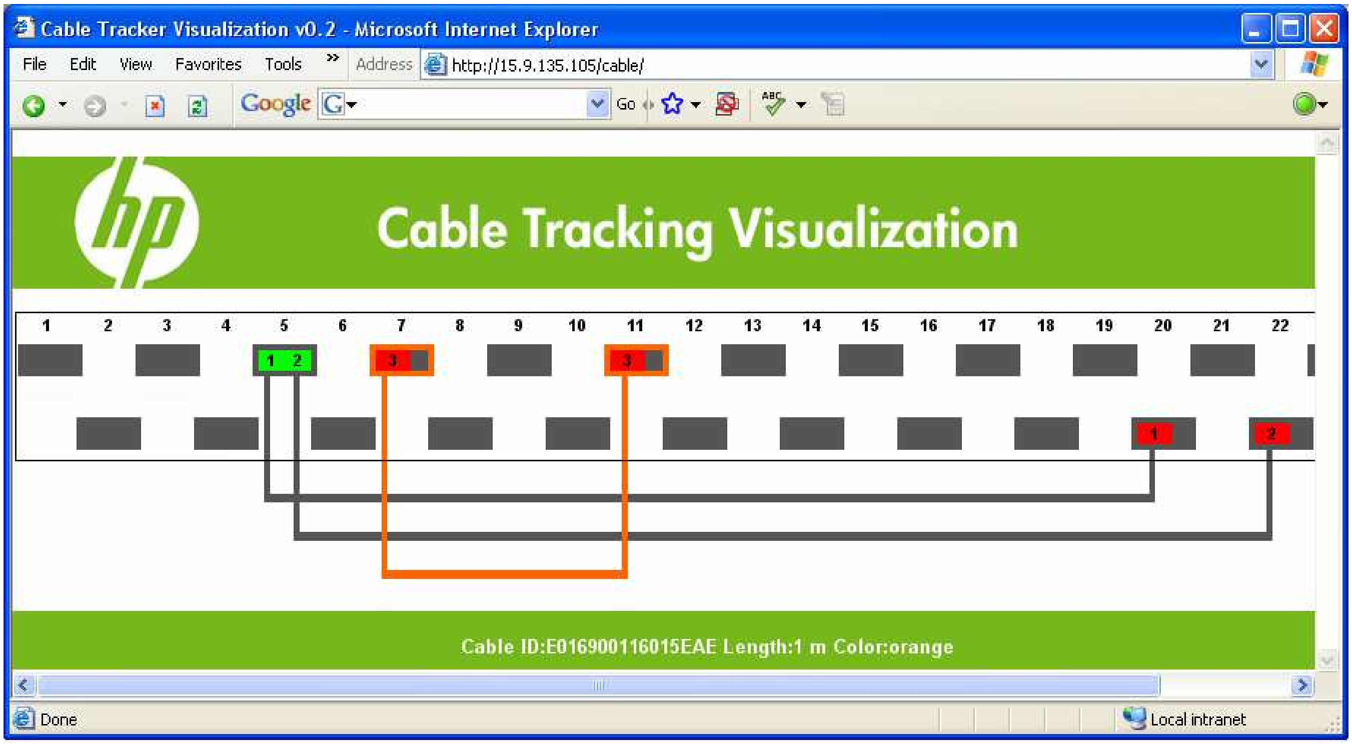


Photo of a 1U - 24 junction antenna array, with 6 single ended and 3 double ended connections.



Cable ID:E016900116015EAE Length:1 m Color:orange

Example of a simplified graphical representation (not the same cable layout as shown earlier picture).

Competitive Approaches: Manual inventories or custom cables

The traditional method for cable tracking is entirely done by hand. Cable positions are manually recorded and attempts are made to maintain records to facilitate change management. This is slow and prone to error. Even with bar coded cable ends the position of the cables is manually recorded. Finally, a manual system is unable to provide timely notification if a cable is dislodged, or placed into an incorrect junction.

Some mechanisms exist for automatically tracking copper cables. These mechanisms use the conductive properties of the cable and only work when a cable is actually connected to a working device on the network. Once connected, only the logical data path is visible not the individual physical cables. Existing solutions for optical cables depend on custom cables which cannot be used to retrofit existing infrastructure [2].

Acknowledgments

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