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Extension of the Optical Switching Architecture to Implement the Moveable Cell Concept

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Abstract To limit the numerous handovers while providing high bandwidth services to train passengers, we proposed the moveable cell concept. In this paper, we extend our switching architecture to realise this concept in more general situations.

Introduction

To provide the current spectrum of multimedia services (e.g. Video-on-Demand, Online gaming, ...) to train passengers, train carriages need huge bandwidths. Therefore, we designed a dedicated cellular wireless network along the tracks consisting of a lot of antennas, e.g. one antenna every 50 to 100 m. This results into frequent handovers, normally leading to large losses. An attractive solution is the moveable cell concept, already proposed in [1] on ECOC 2004. Here, we generalize the concept.

Optical feeder network

To efficiently manage the proposed network, the antennas along the railway (Remote Antenna Units, abbreviated to RAUs) are grouped over a distance of e.g. 5 km and they are under supervision of one central control station. By connecting the control station with the RAUs via an optical feeder network using Radio over Fiber (RoF), complicated signal processing functions (modulating, demodulating,...) can then be transferred to the control station [2]. In this way, each RAU is simplified significantly.

A train is connected to more than one RAU at each moment and all RAUs in the reach of the train could be fed by another radio signal, each signal being provided by a dedicated wavelength. The same feeder pattern can then be repeated for the RAUs in front of and after the train. Such an implementation is very interesting in a train scenario, because there are a lot of users who are concentrated at the same place, while there is typically no one just in front of or after this location. In this case, a ring network is a promising topology.

Moveable cell concept

As mentioned, numerous handovers occur when moving along the RAUs. With moveable cells, we have an efficient solution to this problem. Instead of the train moving along a fixed repeated cell pattern, we consider a cell pattern that moves together with the train (Fig. 1), so that the latter can communicate on the same frequency during the whole connection, also avoiding most, cumbersome, handovers.

Thanks to the central control system, we can

implement these moveable cells by reconfiguring the optical feeder network that feeds the RAUs. In this way, the speed of the cells can rather easily be synchronised with that of the train, but it is also important that the required reconfigurations should be kept minimal. Finally, we stress that the moveable cell concept is extremely attractive in a train scenario, because all users move at the same speed.

Fig. 1: Illustration of the moveable cell concept.

First optical switching architecture

First of all, we emphasize that the reconfiguration needed to implement the moveable cells takes place entirely in the optical domain. A possible way to implement the moveable cell concept was proposed in [1] (cf. Fig. 2). However, there we assumed that the antennas on the train and the RAUs are always equally spaced, e.g. every 50m an antenna on the train corresponds with every 50m a RAU.

Fig. 2: First architecture to implement moveable cells.

RAUs and antennas on the train unequally spaced

In a realistic situation, it will not generally be possible to maintain this perfect match. This has important consequences on the above-considered architecture of the control station. Especially the case where the

number of RAUs within range of the train is smaller than the number of antennas on the train is very important. It is not unrealistic to place one antenna on each carriage (i.e. every ~25 m). To keep an equal distance between antennas on the train and between the RAUs, the distance between successive RAUs also has to be 25 m. This requires a huge amount of RAUs to equip a railway network.

When we consider a RAU spacing up to 50 or 100 m, there are respectively two or four antennas on the train within reach of one RAU. Consequently, each RAU has to transmit several RF signals, and these RF channels also have to be modulated on the same wavelength. This especially has a large impact on the architecture of the central control station.

Another important point of difference with the situation where the RAUs and the antennas on the train are equally spaced, is that the different RAUs will have to switch their frequency on different moments. As a consequence, the number of switching events in the central control station will increase a lot and the switching architecture will become much more complicated. When we want to keep the architecture from Fig. 2, all RAUs have to switch their frequency simultaneously, and the disadvantage of such an implementation is that every cell has to be almost entirely overlapped by its two neighboring cells [3]. To avoid this, we propose a new architecture of the control station.

New optical switching architecture

As in the case where antenna and RAU densities are equal, it is sufficient to provide as much modulators as used RF channels. But now, more optical switches are required, and the AWG has to be substituted by more complicated optical switches. In the presented switching architecture, the modulation of two or more RF signals on one wavelength is done in different steps, which is equal to the number of RF signals modulated on one wavelength.

In our example, we use only three RAUs within range of a train equipped with four antennas. In this case, on one wavelength, we have to modulate two RF signals, and in the proposed architecture, we can clearly recognize two steps (Fig. 3). We can also remark that one moment e.g. RF_1 and RF_2 have to be modulated on the same wavelength, and another moment RF_2 and RF_3 . The two frequencies which are modulated on one wavelength will always be "neighbor" frequencies (neighbor compared to each other on the train). That is why we can modulate e.g. RF_1 and RF_2 in step 1, and RF_2 and RF_3 in step 2, because these two pairs of frequencies will never have to be placed together on the same wavelength.

In Fig. 3, λ_1 carries RF_1 and RF_2 , both antenna 1 and 2 on the train are then within range of RAU 1. λ_2 and λ_3 each carry one RF frequency. The next moment, λ_2 will carry RF_2 and RF_3 . This means RF_4 has to be

switched from the λ_3 to λ_2 . At the same moment, RF_1 comes within range of a new antenna and also switches to a new wavelength.

Fig. 3: New optical switching architecture.

Fig. 4 depicts the number of switching times to span the distance covered by one RAU with the new architecture, and this for 4 antennas on the train. There are some discrete points where this number has a local minimum (number of RAUs within range of the train = 4/3, 2, 8/6 and 4). With the architecture from Fig. 2, this number is 2, but the distance covered by one RAU is then very small. Here, we have 20 switching moments in case of one RAU (Fig. 4), but this corresponds to 5 switching times to span the same distance.

Fig. 4: Number of switching moments.

Conclusions

In this paper, we have extended the optical switching architecture to implement the moveable cell concept. Because the number of switching times is still manageable, we conclude the handover times will also reduce a lot thanks to the concept.

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