Popular Science

Clocks have always been playing an important role in our daily life, since they were invented. They are used in everyday life to keep time, and moreover to organize daily routine. Clocks are required to be accurate and precise; otherwise, we might miss a train. Accuracy of a clock indicates that at a specific moment it reports a time very close to the publicly agreed time (i.e. local or world time). The precision of a clock means that the ticks of the clock should be in the same time interval. A precise clock can be inaccurate if it is not tuned to a correct time at the first place; an imprecise clock can be accurate at a specific time and might be inaccurate from then on.

Within telecommunication network, base stations, to which our mobile phones send and receive data, also need to have an accurate and precise clock in order to operate properly. Specifically, the time difference (time offset) between any two clocks should be less than a few microseconds. In addition, their frequency (cycle per second) difference (frequency offset) should be within 50 ppm (part per million). These stringent requirements cannot be met by low-cost clocks. However, we can use clock synchronization or clock distribution techniques to keep the clocks running accurately and precisely.

One common solution is to install GPS receivers within each base station, which can receive accurate GPS timing signals from the satellites. In this way, base stations can be easily synchronized both in time and frequency accurately. However, GPS receivers are very expensive, and too much reliance on GPS would also be a concern for most countries due to nation security reasons. Actually, there is another traditional solution to synchronize base stations, which is to use traditional telephone transmission lines (a.k.a. E1/T1 leased lines) interconnecting base stations. However, as more and more people use smartphones to listen to music and watch videos online via cellular mobile network, these transmission lines can no longer meet such ever-increasing demand for bandwidth.

For these reasons, network operators are thinking of using Passive Optical Network (PON) as mobile backhaul network since PON can support much larger bandwidth compared to traditional copper lines, in addition it saves deployment cost due to its point-to-multipoint architecture, i.e. using less fibers (shown in figure 1). Furthermore, since PON is one of the most common broadband access technologies we are using nowadays, network operators can easily adopt the same PON infrastructure to be served as mobile backhaul network.

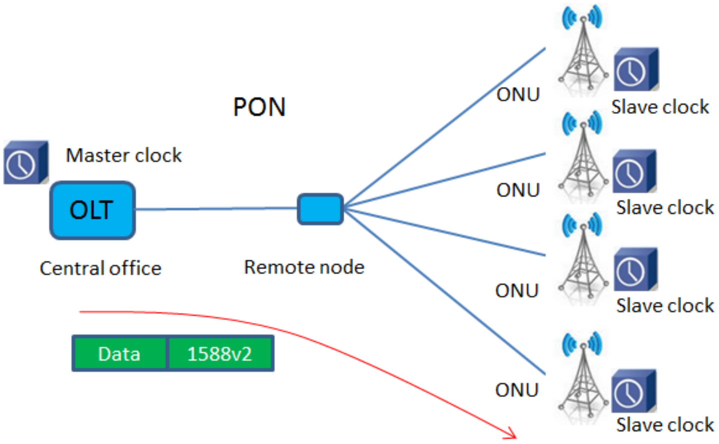

Figure 1 Using PON as mobile backhaul network

PON was originally designed to serve fixed wire-line broadband access, and it was not intended to distribute accurate clock within the network. For this reason, clock synchronization requirement for wire-line access (a few milliseconds time offset) is much lower than that for mobile backhaul network (a few microseconds time offset). As a result, clock synchronization issue in PON has to be addressed in order to serve as mobile backhaul network.

Precision Time Protocol (PTP) is protocol used to synchronize clocks within a network. The idea behind PTP is that the master and slave clocks continually exchange short messages with each other to transfer timing from the master clock to the slave clock. The principle of PTP is quite similar to that of Network Time Protocol (NTP), which most of our personal computers are using nowadays to synchronize to network server via Internet. The main difference between these two is their targeted time transfer accuracy. PTP can achieve level of time accuracy in the range of 100 nanoseconds, while NTP targets level of millisecond.

One might be tempted to wonder if PTP can be used to distribute time (synchronize) over PON. This sounds like a good idea. However, the delay mechanism existing in PON will deteriorate the time transfer accuracy using message-based approach like PTP. For example, the longer distance between central office and base stations, the longer the delay, thus lower accuracy.

To investigate the feasibility of implementing PTP over PON as mobile backhaul network, modeling and simulation were done in my thesis. The simulation results showed that PTP can be implemented over PON, meeting the time synchronization requirement for mobile backhaul network. PTP can achieve time transfer accuracy of sub-microsecond level, in a PON system where there are 256 base stations located up to 100 km away from the central office. The result showed that network operators can deploy PON as mobile backhaul network, using PTP to transfer time over PON. Therefore, number of and dependency on GPS devices in base stations will be much reduced, thus saving a huge amount of money.