Research Report on the Application of Omicron Lab's OTMC 100i Antenna-integrated PTP Grandmaster Clock at BME-MIT

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The Department of Measurement and Information Systems of Budapest University of Technology and Economics (BME-MIT) has been involved in time synchronization related research since the late 1990s. BME-MIT started focusing on real-time, embedded communication and low cost, in-band, standardized time and frequency synchronization solutions that time. We have worked with NTP, TTP/C, TTEthernet, FlexRay, IEEE 1588, SyncE, 802.1as (AVB in general) and some other technologies since then. The Network Embedded Systems Laboratory (NESlab) has been set up in 2010 to coordinate the work on these research and development fields. Currently, BME-MIT and NESlab refocus for the upcoming Time Sensitive Networks (TSN) related research and development.

BME-MIT provides also time and frequency synchronization related education. We include these topics in various courses, such Operating Systems, Embedded Systems, Network Embedded Systems, and Project Laboratory and Theses Works. We have continuous education courses for practicing engineers, which also include these topics (Ethernet and TCP/IP in Embedded Systems, Real-time Network Embedded Systems, etc.).

IEEE 1588 Related Research and Development at BME-MIT

BME-MIT has been involved in IEEE 1588 related research since 2009. The initial research targeted x86 Linux IEEE 1588 slave clock implementations for Intel Network Interface Controllers supporting hardware timestamping. Later, we have developed a Linux based prototype master clock based on these NICs. This this master clock prototype plays a central role in our research, as it is fully customizable and open for fault injection and other experiments, however, for time reference purposes we also need a professional grand master clock. Omicron Lab has donated us an OTMC 100i Antenna-integrated PTP Grandmaster Clock in 2013, and since then we have been using it for reference clock purposes.

The advantages of the Omicron OTMC 100i is the following based on our practical experience:

- Ease of installation and management (antenna integrated, Power over Ethernet),
- Full support of the various options of IEEE 1588v2 (Ethernet, IPv4/UDP or Ipv6/UDP transport, on or two step clock, E2E or P2P messaging, etc.),

Figure 1. Omicron OTMC 100i installed on the southern edge of the roof of Building I of BME with the view of the city

- Simple, but powerful WEB based configuration,
- Good support and regular security updates to address the identified vulnerabilities in various protocols (primarily NTP related issues surfaced in the last two years).

Currently, our research and development focuses on time and frequency synchronization are the following:

- System and device level reliability and dependability of time and frequency synchronization,
- Advanced signal processing for time and frequency synchronization including clock servos,
- System management related aspects of time and frequency synchronization,
- System and device development for time and frequency synchronization solutions and for applications (contract engineering and consultation).

We work on IEEE 1588, IEEE 802.1as and TSN related projects using Intel, Texas Instruments microcontrollers and application processors primarily (Linux and FreeRTOS operating systems), FPGA based custom hardware, and Cisco and MOXA Ethernet switches.

Detailed evaluation of the OTMC 100i

Omicron Lab has donated the OTMC 100i in 2013. It was installed on the southern edge of the rooftop of the building of the department, and since then it is operating without problems. See Figure 1 for the installation, and Figure 2 for GPS location. Installation on the southern edge of the rooftop is acceptable as the visibility of GPS satellites is good on the latitude of Budapest, Hungary. The installation was done using the supplied connector and quality UV and weather resistant CAT6 fully twisted pair cable. The location is close to the radio room of the building, where the device can be connected to the structured cabling system of the building. The supplied power injector, IEEE 1588 compliant networking equipment, and other devices used in the measurement setups are located in one of the cabling room of the department.

Setting up the OTMC 100i was easy. We assign a static IPv4 address based on the Ethernet address using DHCP for the device. The IPv6 address is assigned using SLAAC based on the Ethernet address also. After that the device can be set up according to the actual requirements and can be monitored using SNMP. In various project we used nearly all IEEE 1588 (the name PTP is used on the WEB based GUI) and NTP specific settings of the device. The WEB interface is intuitive and self-describing for engineers with basic knowledge of networking as general, of course, the fundamental understanding of IEEE 1588 and NTP is also required for set up and operation.

We have used the OTMC 100i in multiple projects:

- Analyses of reference clock connection methods for IEEE 1588 master clocks. The results are published in the proceeding of the 2015 ICCC conference.
  See http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7145082 for detailed information.
- Reliability analyses of the Best Master Clock (BMC) algorithm and enhanced solutions to improve the quality of clock synchronization in case of multiple available master clocks. The results of this research is to be published. We use the OTMC 100i as one of the master clocks in the setup. We use our own prototype master clock to inject faults into the system and cause failures in BMC. We will propose some solutions to enhance the performance of IEEE 1588 in case of failures that do not influence the fundamentals of the protocol.
- IEEE 1588 slave clock setup, development and testing for BeagleBoard Black and for various microcontrollers, FPGA cards, etc. as Project Laboratory or Theses Works for students.

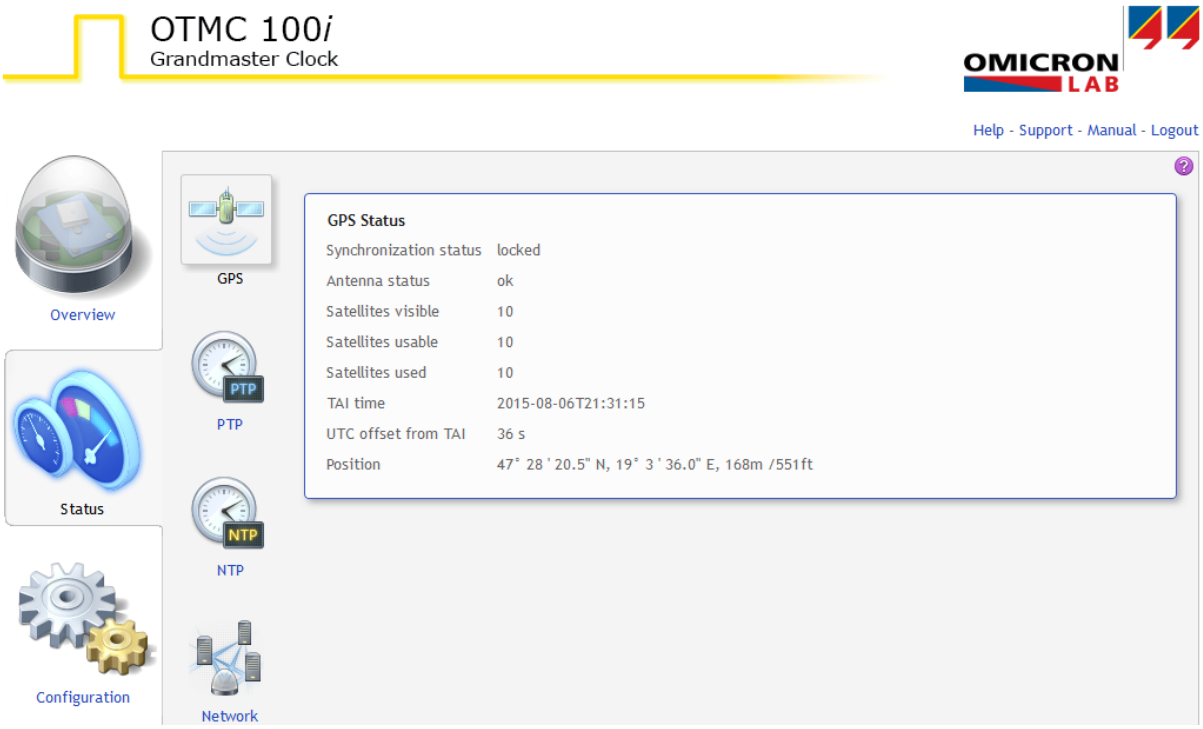

Figure 2. Omicron OTMC 100i GPS Status screen showing the location of the equipment

- IEEE 1588 compliant FPGA based custom switch development. The OTMC 100i is used as master clock in the test system, reference clock output was provided with an additional timing GPS receiver with a custom interface to compensate cable delay.

We have received timely updates on various known security issues, primarily effecting NTP only, in the last two years. Installing the updates has never caused any malfunctions.

The only visible disadvantage of the OTMC 100i in our application is that it does not have an auxiliary reference time output for measurements due to its antenna integrated construction; however, Omicron Labs's TICRO 100 can provide that feature in a laboratory, if required. The lack of auxiliary reference time output is understandable, as the Omicron OTMC 100i is primarily designed for industrial applications in our view, where simple installation, ruggedness, and ease of operation are in the center of interest.

About the author:

Tamás Kovácsházy received the M.Sc. degree in electrical engineering and the Ph.D. degree from the Budapest University of Technology and Economics, Budapest, Hungary, in 1994 and 2008, respectively. He is currently an Associate Professor with the Department of Measurement and Information Systems (BME-MIT), Budapest University Technology and Economics. Currently, he is the head of the Network Embedded Systems Laboratory of BME-MIT. His research interests are network-embedded systems, real-time communication in embedded systems, network clock and frequency synchronization, and software technology for embedded systems.