SEVEN Solutions
When every nanosecond counts

White-Rabbit RoE for Distributed Communication Systems
Defense Applications

Radio-over-Ethernet (RoE) allows the distribution of data and timing over networks. It is used for distributed telescopes, radars, ultrasound sensors and distributed communication emitters/receivers (cognitive radio systems, phased arrays, etc). It improves system performance, simplifies deployment and reduces cost and cabling weight.




User Challenges

- Provide synchronization trigger signals to ADCs/DACs with an error better than 1 ns over areas of tens of meters up to several kilometers.
- Disseminate common frequency values with a phase-noise jitter below 1 ps in those areas, including temperature compensation mechanisms.
- Provide programmable frequencies, triggers or phase delay capabilities.
- Use flexible ring and/or start network topologies with high scalability (tens to thousands of end nodes) and several hops over up to 20 cascaded devices.
- Distribute data and commands within the same interface using standard Ethernet software tools.
- Provide interoperability with COTS devices based on Ethernet interfaces.
- Allow the utilization of networking configuration and monitoring tools.
- Provide failover mechanisms and timing error detection features.
- Integrate self-calibration capabilities for easy deployment and commissioning.
- On some applications, reduce cabling and its associated weight.

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Context

Currently, most distributed sensor systems rely on GNSS-based time synchronization, which can easily be jammed or even spoofed. In this framework, unprecedented performance has been achieved quickly by integrating new distributed communication technologies and sensor systems. We can highlight distributed telescopes, radars, ultrasound sensors or distributed communication emitters/receivers (for example cognitive radio systems or phased arrays) among many others that now have significantly enhanced features thanks to a tightly coordinated operation capability. This allows the integration of information from multiple devices scattered across small or large areas and improving signal sensibility as well as signal to noise ratio (SNR).

New radar positioning accuracy, available bandwidth for broadcasting communication systems, and efficient use of the electromagnetic spectrum for modern cognitive radio systems strongly rely on timing-related features. They provide synchronization of distributed triggers in data acquisition or distribution of a shared signal sample-based on shared frequencies, provided with high stability along multiple devices.

This approach involves a single Ethernet solution for communication and sensor data distribution, along with timing information over the same cable (shared physical link). Although this can be developed using customized cables or photonic elements such as Radio over Fiber solutions (RoF), the concept of Radio over Ethernet (RoE) has recently emerged as a more evolved and improved approach. In this case, not only timing, but also commands or data can be distributed over the same Ethernet link without additional cabling.

The Solution

Recently, the new IEEE-1588-2019 HA protocol has been launched. This new version includes an extension for wide area network (WAN) utilization, cybersecurity mechanisms and the High Accuracy (HA) profile to distribute time and frequency with a performance better than 1 ns and a very low jitter. As indicated in the standard, this profile is strongly based on White-Rabbit protocol. White-Rabbit was conceptually designed at CERN and translated into an industrial concept by Seven Solutions, which is now the leading company in the field of sub nanosecond timing with thousands of devices distributed worldwide for different segments. We have demonstrated its scalability to distances of thousands of kilometers, and how its accuracy is kept across multiple hops, as well as the capability to integrate the technology using existing optical telecommunication networks. Moreover, Seven Solutions' IEEE-1588-2019-HA implementation provides network-based failover, inter-links monitoring and interoperability with multiple time protocols. Frequency stability is kept within picosecond-level RMS jitter and phase delay control allows the user to implement the most accurate RoE solution available in the market.

The full solution includes an IP core to be integrated into the user FPGA systems (the **HATI IP** core), provided that the platform includes 1/10 Gbps Optical Ethernet interfaces. All data and ultra-accurate timing can be provided on a single Ethernet link, making the required cabling more compact and lighter. As shown in the figure below, the complete solution integrates accurate RoE fanout devices (WR Z16), compatible with L1 switching and aggregation capabilities as well as a DISA (Defense Information Systems Agency) approved, trusted and secure master timing reference (Orolia SecureSync) for reliable operation. Additionally, system resilience can be improved by using redundant Ethernet links (network based resiliency) or adding rubidium oscillators to the end nodes (system integrated resiliency).

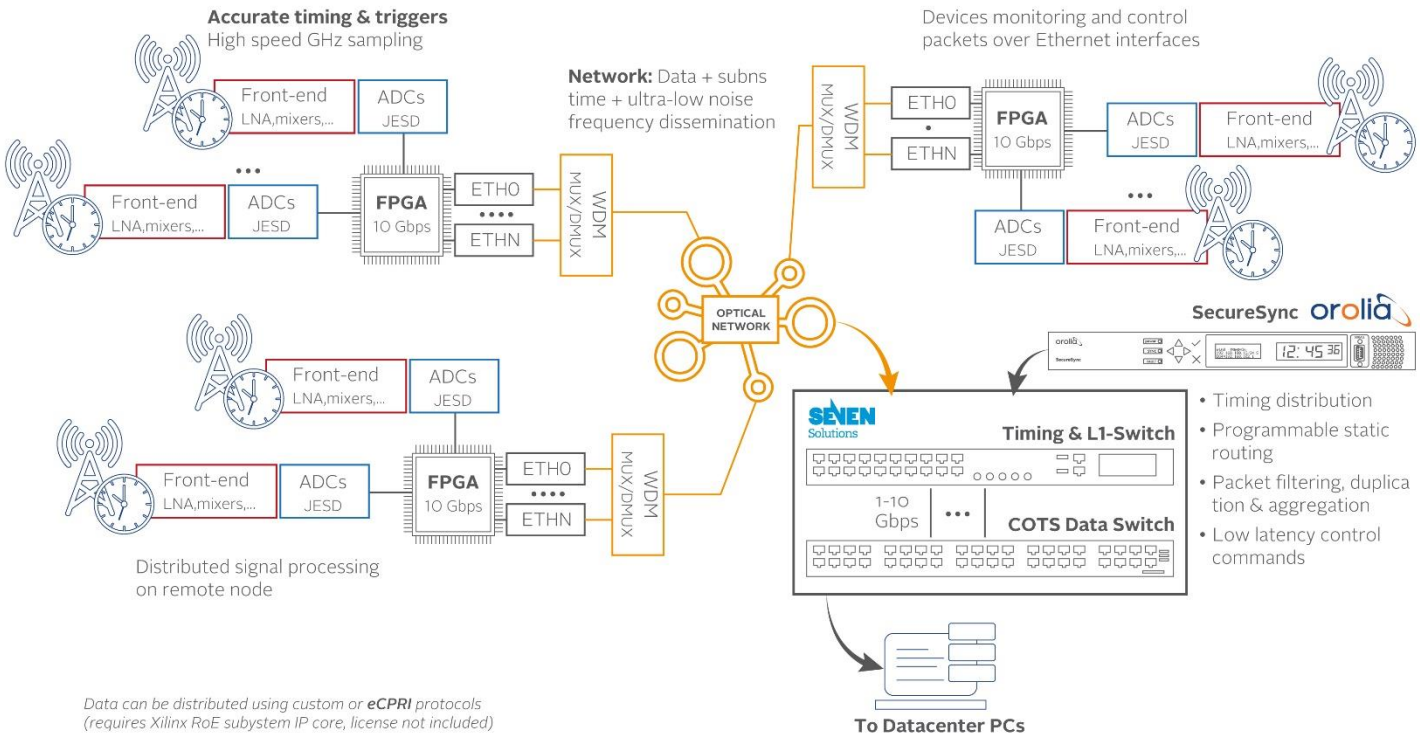

Figure 1.Example of RoE utilization for distributed communication ground segment facility

Results

This solution is based on the most advanced time transfer solution available in the market and implementation of the White-Rabbit/IEEE-1588-2019-HA protocol offered by Seven Solutions. We can provide synchronization performance over hundreds of kilometers with time errors below one nanosecond. Moreover, the system can cascade more than twenty devices connected in a daisy chain ring topology with the same performance. This allows a scalability of thousands of synchronized sensors, making it possible to deploy outstanding distributed submarine ultrasound sensors using hundreds of devices or better positioning accuracy on radar systems.

The same solution is also able to disseminate programmable frequencies with controllable phase delay. The stability of this technique can meet the needs of the most exigent communication systems, as indicated on the figure with remarkable low phase noise values (below one

picosecond) for integration ranges from one to 100 KHz and much better if this integration range is reduced (as required for most military communication applications based on distributed ADCs and DACs). It is important to remark that this performance in synchronization and frequency dissemination is provided while the Ethernet link is working with data distribution and bandwidth usage above ninety percent of the link capability, leaving the timing features unaffected when simultaneously communicating data over a single cable.

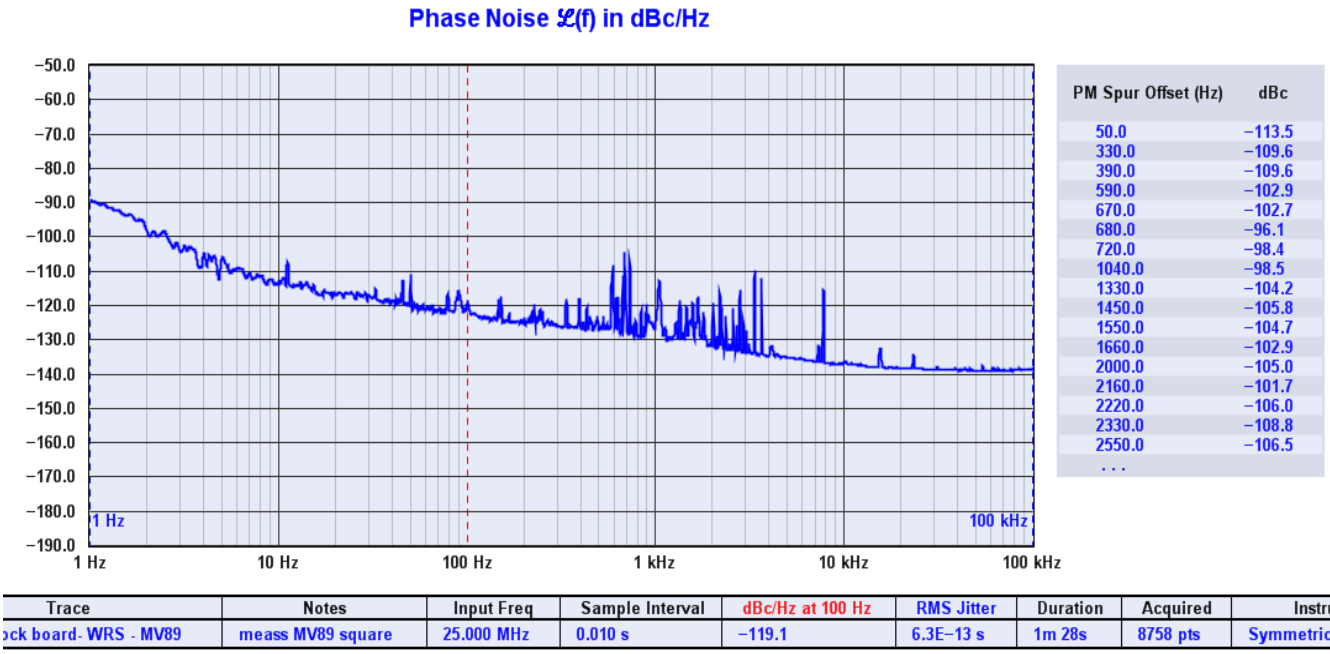

Figure 2. Phase noise of a 25MHz signal distributed over 5 Km of fiber using Seven Solutions White-Rabbit technology

These results make the whole solution very useful for many high-end applications and particularly for the defense sector. As an example, a real application based on ULF antenna synchronization is illustrated in the figure below.

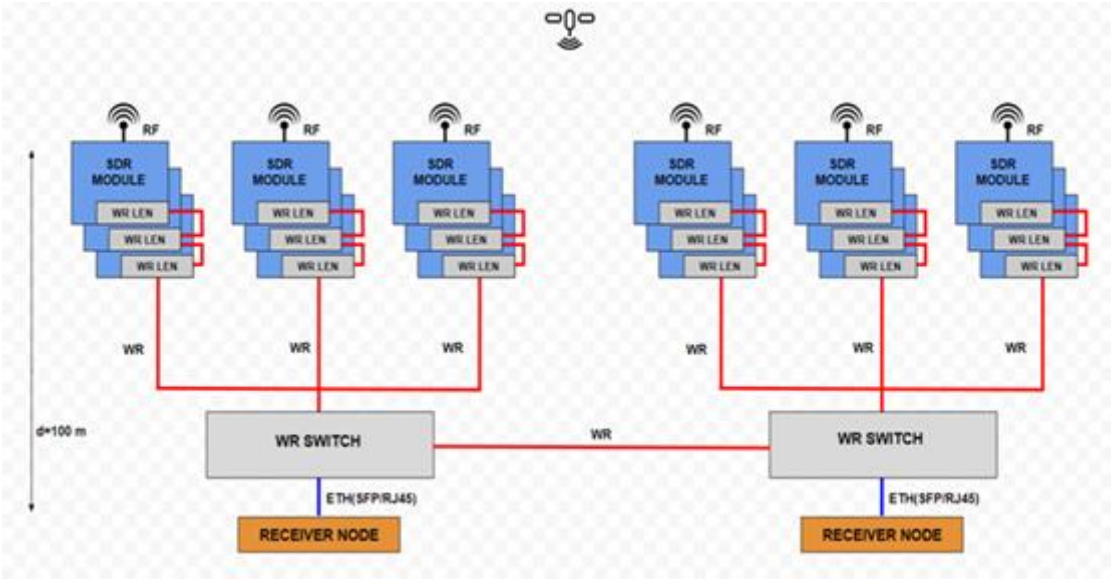

Figure 3. ULF antennas synchronization example

Conclusions

Better timing is like a better optical lens in a camera, when it comes to analyzing and interpreting data gathered from distributed elements. Delivering low-jitter frequencies to software defined radio (SDR) and cognitive radio elements using existing Ethernet connections will reduce cabling and improve the spectrum analysis capabilities of next generation systems. This will facilitate the use of small available spectrum areas required for military ad-hoc network deployment and provide greater flexibility in the use of the electromagnetic spectrum through software defined techniques. All of this is possible thanks to an improved communication bandwidth with reduced interference, due to the reduction of the communication guard bands when tightly adjusting communication timeslots among accurately synchronized emitters.

In summary, the defense timing solutions offered by Seven Solutions and Orolia fully address distributed sensors and communications needs. They are very scalable and applicable to distributed ground segment facilities or to multiple sensors located on aircraft or ship systems. Moreover, the solution is self-calibrated. It does not require measuring cable lengths or developing temperature compensation techniques, which simplifies the error-prone calibration stages required on RoF or other wired technologies. All of these solution features significantly help to reduce deployment costs and commissioning complications.

Finally, by using a single Ethernet cable we can reduce cabling weight, be interoperable with other Ethernet COTS devices, allow the utilization of existing networking tools and provide resilience features based on network topologies.

About Seven Solutions

Seven Solutions S.L. is a privately held company with high expertise in embedded systems and leading accurate sub-nanosecond time transfer and frequency distribution for reliable aerospace and defense, industrial and scientific applications. With more than ten years of expertise in embedded systems design (electronics, firmware, embedded software), we offer the best-in class full turn-key solutions as well as customized solutions for timing applications. We are leaders in time and frequency distribution solutions based on White-Rabbit technology and derived standards (IEEE-1588-2019-HA). www.sevensols.com

About Orolia

Orolia is the world leader in Resilient Positioning, Navigation and Timing (PNT) solutions that improve the reliability, performance and safety of critical, remote or high-risk operations, even in GPS denied environments. With a presence in more than 100 countries, Orolia provides virtually fail-safe GPS/GNSS and PNT solutions for military and commercial applications worldwide. www.orolia.com

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