TT ETHERNET

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WHAT IS TTETHERNET?

- TTEthernet stands for Time-Triggered Ethernet.
- Time-Triggered Ethernet is a scalable networking technology that uses time scheduling to deliver deterministic real-time communication over Ethernet.

HISTORY

- TTTech developed Time-Triggered Ethernet to enable deterministic communication over Ethernet, overcoming the limitations of traditional Ethernet's lack of determinism.

- TTTech is an Austrian company that specializes in real-time networking and safety controls. The company released its proprietary protocol in the early 2000s.

- Due to its determinism, fault tolerance, and high reliability, TTEthernet gained popularity and was made an open standard. SAE International (Society of Automotive Engineers) released the standard SAE AS6802, in November 2011.

HISTORY

- In 2008, it was announced Honeywell would apply the technology to applications in the aerospace and automation industry.

- In 2010 a switch-based implementation was shown to perform better than shared bus systems such as FlexRay for use in automobiles.

- Since then, Time-Triggered Ethernet has been implemented in different industrial, space and automotive programs and components.

FEATURES OF TTETHERNET

- TTEthernet operates on OSI layer 2 and allows the usage of existing upper-layer protocols on top of Time-Triggered Ethernet.
- TTEthernet can be configured to operate as a **master-slave** synchronization protocol or **multi-master** synchronization protocol.
- It has been specifically designed for safe and highly available real-time applications, cyber-physical systems and unified networking.
- It is fully compatible with IEEE 802.3 Ethernet and integrates transparently with Ethernet network components.

HOW IS TT-ETHERNET USEFUL?

ETHERNET ORIGINALLY WAS NOT DESIGNED TO SUPPORT TIME-CRITICAL APPLICATIONS, DETERMINISTIC OR SAFETY REQUIREMENTS. TIME-TRIGGERED ETHERNET EXTENDS THE CAPABILITIES OF TRADITIONAL ETHERNET TO MEET REQUIREMENTS LIKE FULLY DETERMINISTIC COMMUNICATION, FAULT TOLERANCE , SYNCHRONIZATION SERVICE, GUARANTEED CONSTANT LATENCY, AND PARTITIONING OF NETWORK TRAFFIC.

Determinism

Synchronization

Guaranteed timing

TTEthernet is very useful when it comes to the **Aerospace Industry**.

It uses a partitioning technique to deliver instrument signals together with entertainment systems, electronic navigation and guidance systems and internet access to the passengers, all of these can be integrated into one single network, which saves the cost of wires and network components.

Partitioning happens at the network level to deliver additional functionality to critical applications.

This makes sure that the traffic generated by critical applications takes precedence over traffic generated by non-critical applications.

All TTEthernet devices synchronize their local clocks, enabling a time-triggered mechanism to establish and maintain a global time. This global time allows TTEthernet to use mechanisms like **Temporal Partitioning** to provide a highly available system. In the multi-master system, a grandmaster is elected for synchronization.

TTETHERNET FRAME

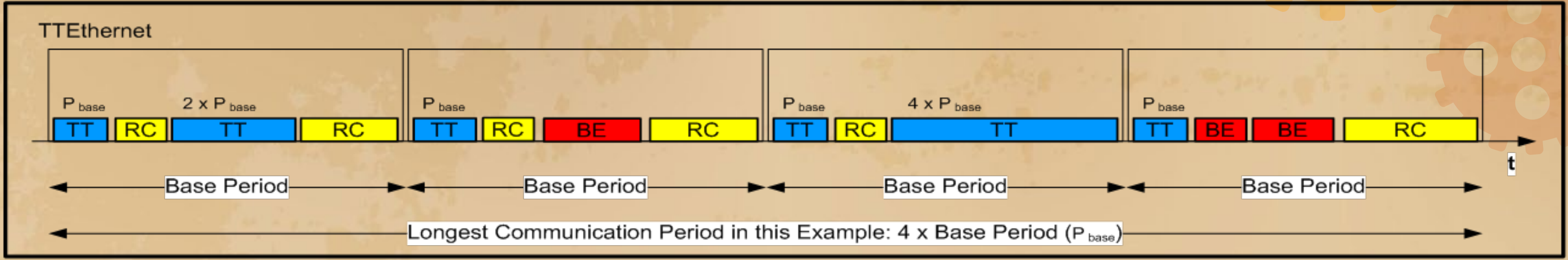
7 bytes	1 byte	4 bytes	2 bytes	6 bytes	2 bytes	46 – 1500 bytes	4 bytes	12 bytes
Preamble	SFD	CT Marker	CTID	Source Address	Length	Data Payload	FCS	IPG

Preamble: 7 bytes
SFD: Start Frame Delimiter (1 byte)
CT Marker: Critical Traffic Marker (4 bytes)
CTID: Critical Traffic Identifier (2 bytes)
Source Address: 6 bytes
Length: 2 bytes
Data Payload: 46 – 1500 bytes
FCS: Frame Check Sequence (4 bytes)
IPG: Interpacket Gap (12 bytes)

TTETHERNET FRAME

- **Preamble:** It allows the receiver to synchronize with the timing of the received data.
- **SFD:** It is used to indicate the start of a new frame.
- **CT Marker:** It is used to distinguish time-triggered frames from other Ethernet traffic.
- **CTID:** It is used by the switches to route time-triggered frames through the network.
- **Source Address:** Defines the MAC Address of the Source.
- **Length:** It is used to contain the payload length.
- **Data Payload:** The actual data payload, occupying between 46 and 1500 bytes.
- **FCS:** It is used for error detection.
- **IPG:** It is required before the transmission of a new frame.

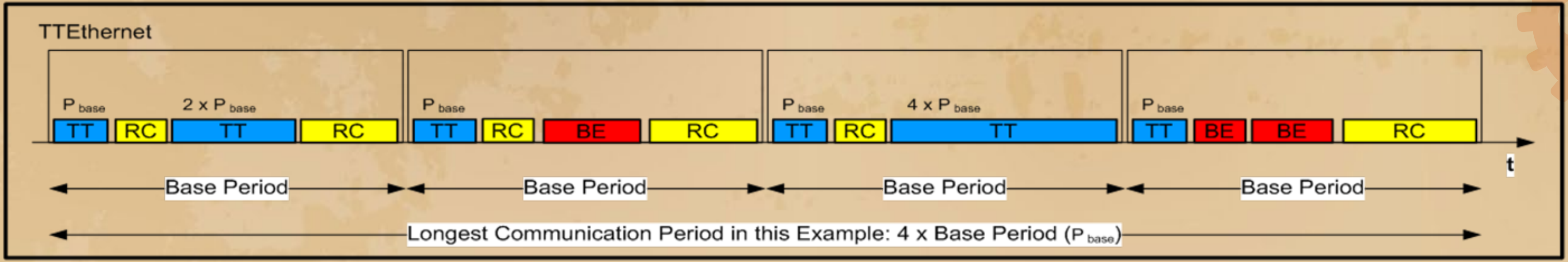
TTETHERNET MESSAGE



- ✓ Time-triggered Ethernet (TTE) frames include both control and data information.
- ✓ There are three traffic classes and message types provided in the current TTEthernet Switch Implementations:

- ➢ Time-triggered traffic
- ➢ Rate-constrained traffic
- ➢ Best-effort traffic (including VLAN traffic)

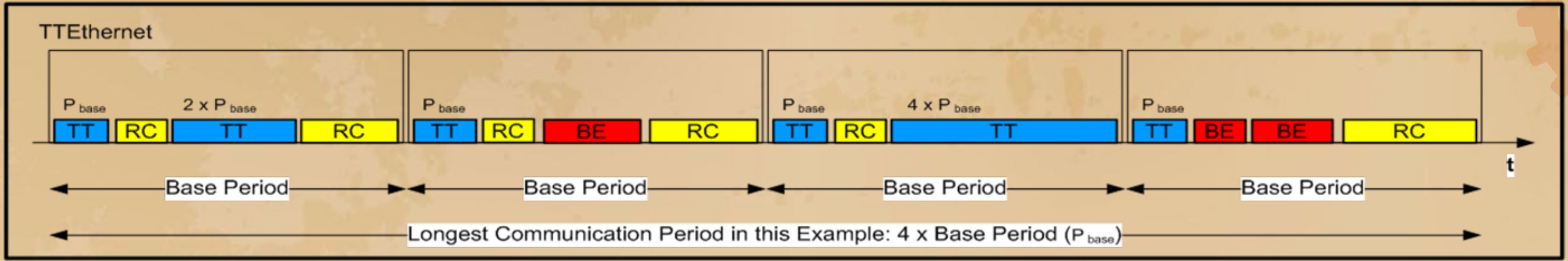
TTETHERNET MESSAGE



- **Time-triggered (TT) traffic:** This occurs in a time-triggered way, where messages are transmitted in a predictable period with guaranteed timing. This is achieved by the forwarding schedule which also prevents collision. This type of traffic is sent over the network with constant communication latency and minimal and bounded jitter (interruptions).

✓ **Frame type:** TT frame contains a header with timing information and a data payload.

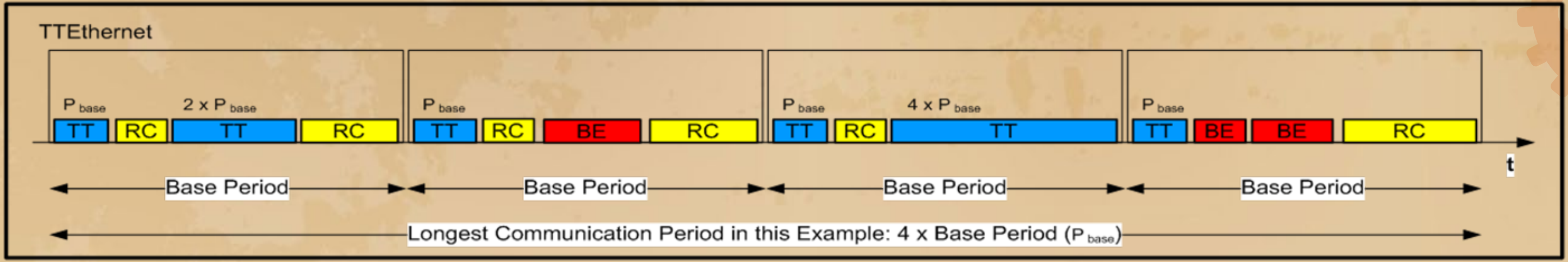
TTETHERNET MESSAGE



- **Rate-constrained (RC) traffic:** RC packets are sent with bounded latency and jitter means with a specific interval. Each Time-Triggered Ethernet sender node gets a reserved bandwidth for transmitting messages with the RC traffic. Clock synchronization is not necessary for RC message exchange.

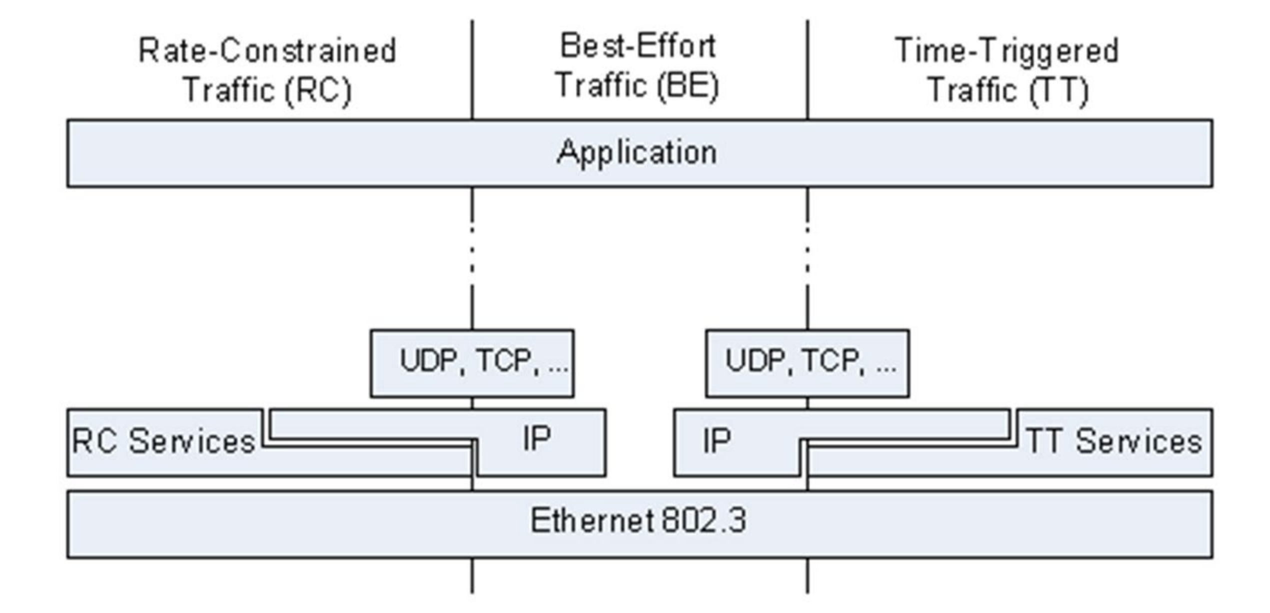
- ✓ **Frame type:** In RC traffic, frames only contain data payloads without additional timing information.

TTETHERNET MESSAGE

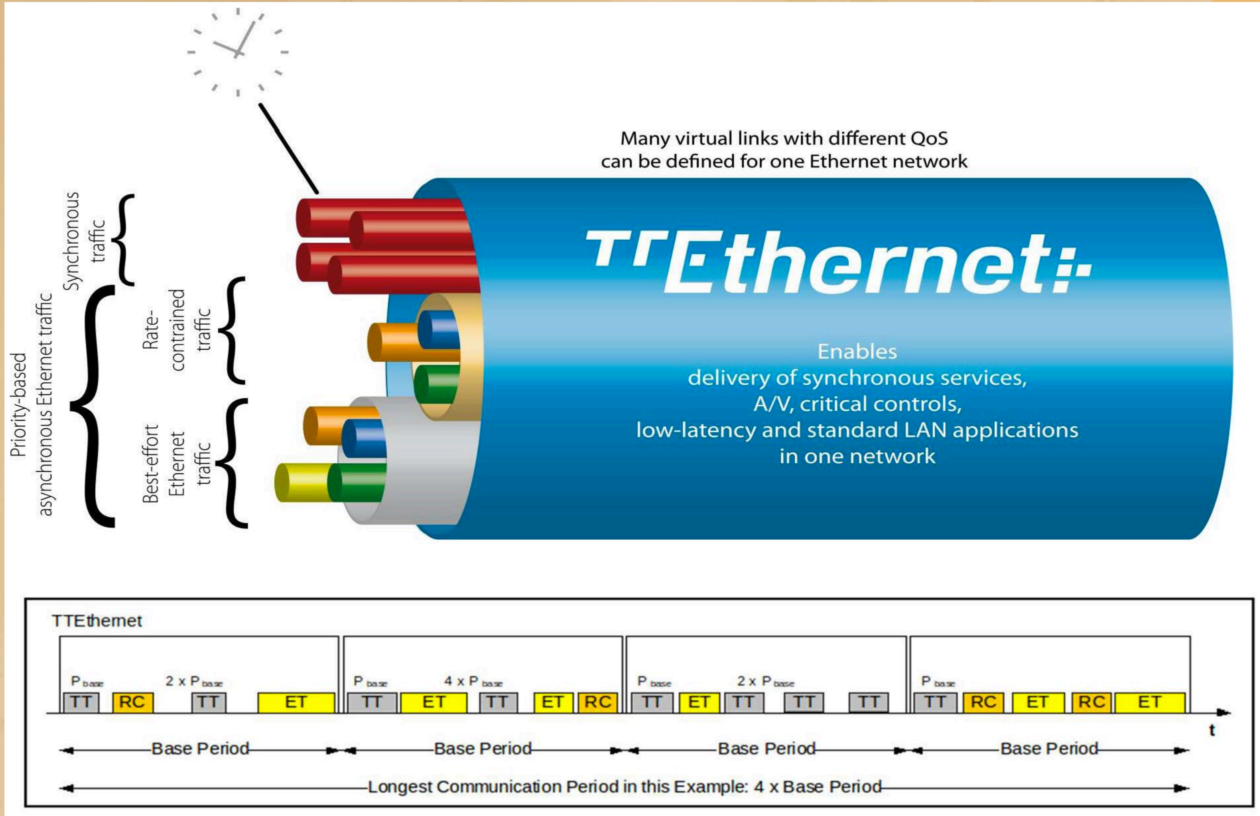


- **Best Effort:** This type of traffic does not come with timing guarantees. It does not allocate a specific amount of bandwidth & time guarantee. BE traffic class is compatible with the IEEE 802.3 standard Ethernet traffic. Packets that are part of the class are sent whenever the network resources are available (CSMA/CD).

TTETHERNET MESSAGE



TTETHERNET MESSAGE



TTETHERNET VS ETHERNET FRAME

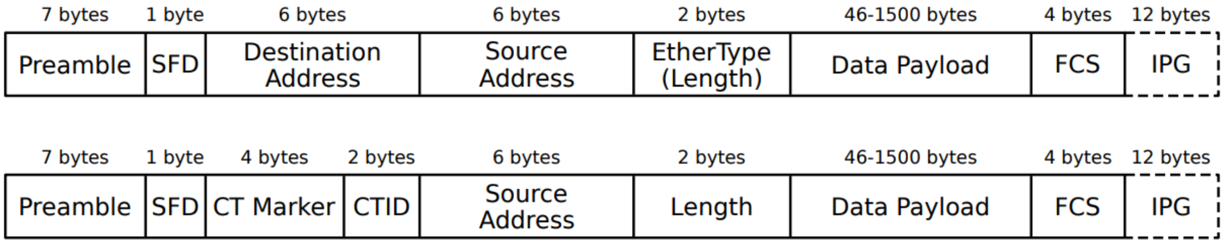


Figure 3. Structure of 802.3 Ethernet (top) and Time-Triggered Ethernet (bottom) frames (layer 2 only).

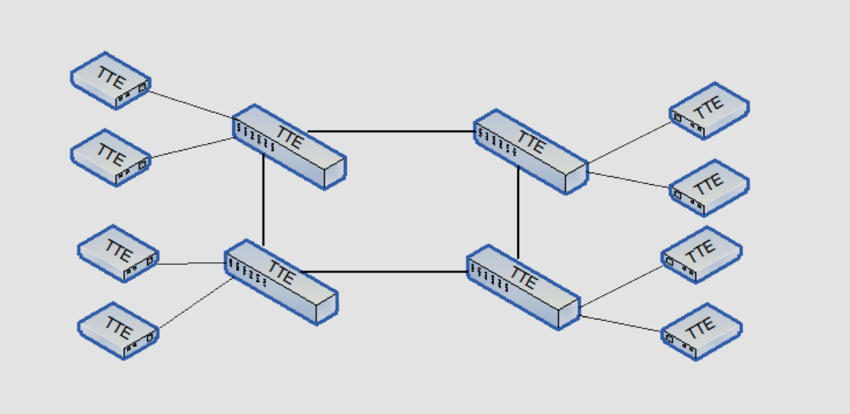
- In the Ethernet frame, the EtherType or Length field, along with the MAC address fields, composes the Ethernet header. The only changes necessary to transform a standard Ethernet frame into a time-triggered frame (with no encapsulated protocol) are within this Ethernet header.

- In place of the MAC destination field is a 4-byte CT Marker and a 2-byte CTID. The CT Marker is a static identifier used to distinguish time-triggered frames from other Ethernet traffic. The CTID is used by the switches to route time-triggered frames through the network. Finally, the last 2 bytes of the header are expressly used to contain the payload length.

RING TOPOLOGY

In the ring topology, only TTE switches are connected in the ring, and the end systems are connected to their respective switches. The advantage of the ring topology is the toleration of link failures among the switches.

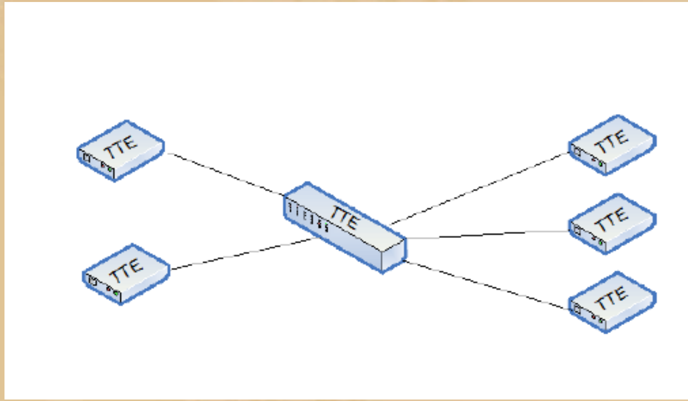
- Switches in the ring are responsible for sending TT & RC messages redundantly at each end, this enable continuous exchange of critical traffic even in the presence of single link failures.
- BE frames are only transmitted over one communication path.
- In case of failure, Spanning Tree Protocol (STP) will find the new logical path.



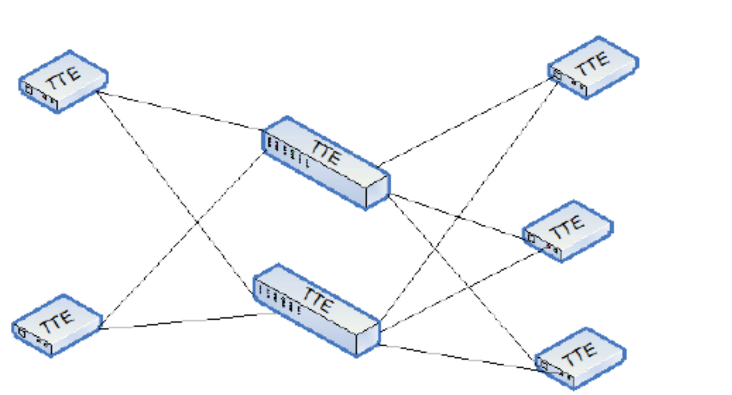
❖ STAR TOPOLOGY

Star topology supports up to triple-channel configuration.

Single Channel Configuration



Dual Channel Configuration



COMMUNICATION

- **Cable type:** RJ-45 UTP/STP, and Fiber-Optic.
- **Speed:** Operates at rate of 100Mbps to 1000Mbps and can go up to 10Gbps.
- Distance depends on what type of cabling we use
- Full Duplex Communication

APPLICATIONS

- TTEthernet is primarily used in avionics and space programs, and it is not commonly utilized in industrial control systems.

- NASA and the European Space Agency (ESA) have selected it for use in space applications, including the **Orion MPCV** and the **European Service Module**, as well as the backbone network for **NASA's Lunar Gateway**.

- When TTE was used in Orion, it was said that it was 1000 times faster than the old space shuttle systems.

ADVANTAGES

- **Deterministic Communication.**
- **Partitioned:** Virtual separation of traffic classes, enables convergence of other protocols on one physical network.
- **Integration of Different Applications:** It is well suited for converged networks & integrates installed industrial Ethernet protocols including Profinet and EtherNet/IP.
- **High Availability:** TTE allows the system to operate even in the presence of a failure.
- **TTE devices are provided with hardware that provides fault tolerance and containment**, to enhance safety, and to ensure continuous system operation.

ADVANTAGES

- **Scalable:** Scales from small to very large systems without compromising safety, security or performance.
- **Secure:** Existing security standards and management features are implemented, and partitioning prevents denial of service.
- **Safe:** Certifiable for fail-operational safety systems.

LIMITATIONS

- Not easy to set up, requires expertise and experience.
- Vulnerable to PCspooF attacks
- Expensive
- Difficult to migrate, especially with legacy instrumentation
- It has specialized Transmitters & Actuators, usual industrial instruments are not compatible
- It has a vendor limitation
- Requires specialized hardware and switches which can support TTEthernet.

LIMITATIONS

PCspooF Attacks:

- At a very high level, the attack works by disrupting a synchronization mechanism in TTE, or more specifically: its protocol control frames (PCF).
- Disrupting these frames would require access to the network: think malware in a compromised non-critical device, or a malicious connected box of electronics.
- Once the attack is underway, the TTE devices will start sporadically losing synchronization and reconnecting repeatedly.
- A successful attack can cause TTE devices to lose synchronization for up to a second, thus failing to forward "tens" of time-triggered messages and causing critical systems to fail.
- In the worst case, PCspooF causes these outcomes simultaneously for all TTE devices in the network.

YOUTUBE VIDEOS

Discover TTTech Aerospace - TTTech

TTEthernet - TracketPacer

REFERENCES

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THE END