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Zero Trust Chain (ZTC): Security Solutions for 5G Networks with an O-RAN-Centric and Device-Centric Approach

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ABSTRACT

● Our team, named Zero Trust X (ZTX), proposes a software solution that enables military squads to securely share situational awareness in their operations through high-performance, but often untrusted, 5G networks.
● It will allow DoD operators to discover malicious entities in near-real-time and provide communication mechanisms to avoid adversary's control over DoD traffic.
● Specifically, through a minimum amount of cooperation with the network operator, part of our solution leverages O-RAN for new threat monitoring and mitigation solutions specifically designed for 5G networks.
● We complement this *O-RAN-centric* approach with a *device-centric* approach to ensure that DoD devices also implement their *own layer of security.*
● Such a combination will substantially enhance the security of the whole system.

Device-Centric Threat Monitoring/Mitigation

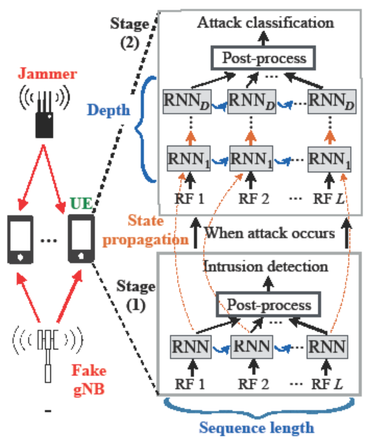


Fig.1.a

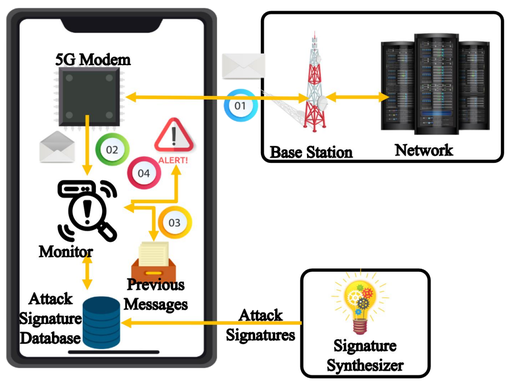


Fig.1.b

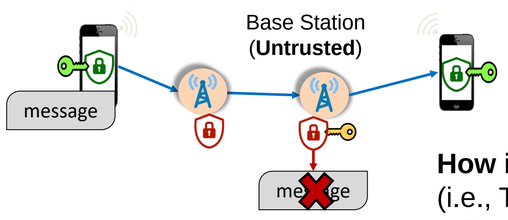
Waveform-Level Intrusion Detection (Fig. 1.a)

● RNN-based solution have a detection performance that improves with increased signal observation length and network depth.
● Two-stage, hierarchical RNN intrusion detection method:
- Stage 1: Intrusion detection. Low-complexity, direct UE implementation that enables near-Real Time intrusion detection with small power consumption. (Single layer RNN)
- Stage 2: A higher-complexity, multi-layer RNN executed on the UEs for categorizing the threat.

Control Plane Threat Detection (Fig. 1.b)

● 5GThreatDetector have two main components:
- (1) An automatic signature synthesizer for capturing attacks.
- (2) A runtime-monitor for monitoring the device's cellular network traffic for those behavioral signatures and taking corrective measures based on its deployment.

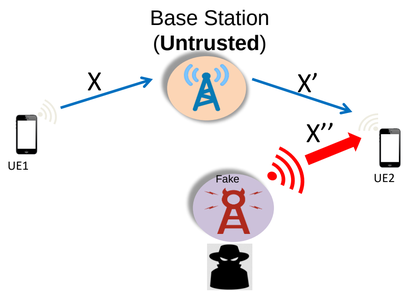
Adaptive Double-Layer Encryption



What is Double Layer Encryption (DLE)?: DLE is the outer layer encryption done by the customer at his UE application layer, whereas the inner layer encryption is any other encryption done/ installed/ operated by a phone manufacturer, system operator, or anyone else.

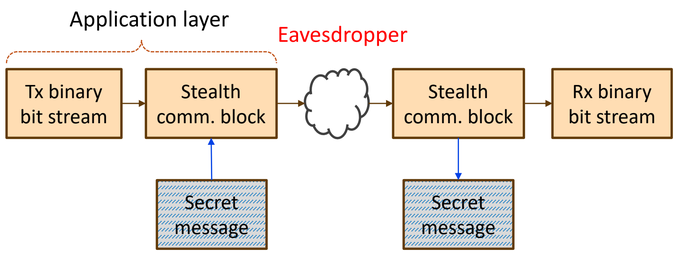
How it works?: ●Encryption key is selected by the customer (i.e., TX), and shared with the RX in prior to communications.
● The DLE software is installed by the customer himself at his phone application layer.
● The DLE key is the one-time password and can be delivered to a user through several channels.

Integrity Check



How to check integrity at Rx?: Tx appends a tag $T = h(K, M)$ to the message M, where K is the shared secret key between Tx and Rx, and h is a hash function. Compared to network-based detection schemes, this approach does not require data collection and analysis from multiple UEs and gNBs. Therefore, the network protocol overhead, implementation complexity, and detection latency can be significantly reduced.

Stealth Communication

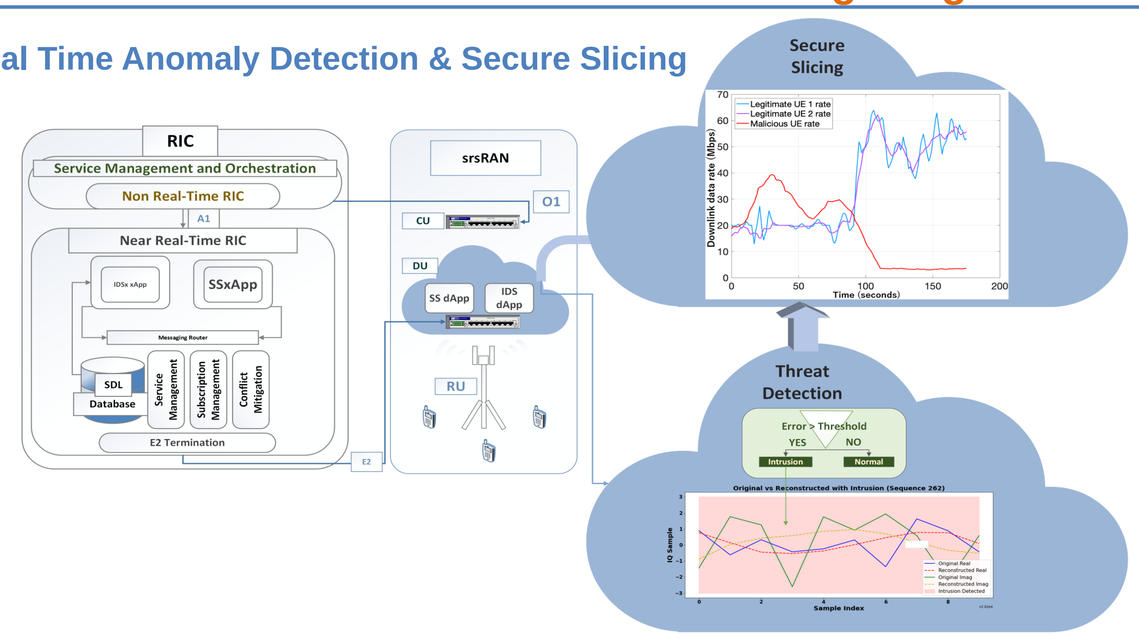


Security Challenge: ● 5G systems do not have any extra layer for secrete message transfer.
● Error permeates to the application layer when CRC-misdetection happens.

ZTX solution: ● An extra error correcting layer + codeword distribution adaptation using secrete encoding/ decoding.
● The stealth communication block combines these error correcting blocks with secret message encoder/decoder.

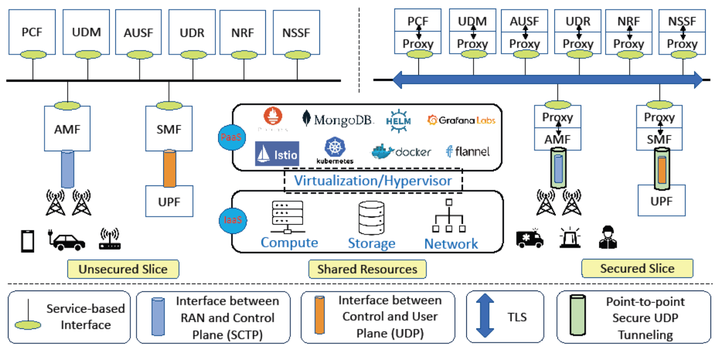
O-RAN & Core-Centric Threat Monitoring/Mitigation

Real Time Anomaly Detection & Secure Slicing



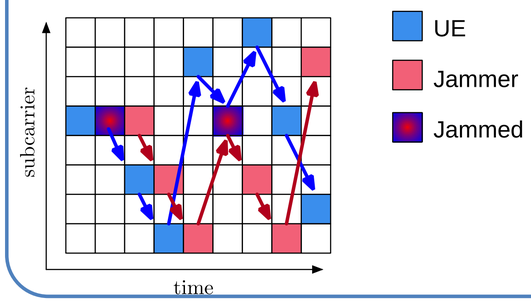
● **Dynamic Anomaly Detection**: Real-time anomaly detection in O-RAN utilizes advanced algorithms to autonomously monitor traffic patterns, promptly identifying security breaches or performance issues. Integration of AI enables adaptive security measures, dynamically adjusting security policies to counter evolving cyber threats.
● **Secure Slicing for Protection**: Secure slicing partitions network resources in O-RAN, isolating sensitive communications from other traffic, minimizing the attack surface, and enforcing strict access controls and encryption measures.

Core-Centric Threat Mitigation



● We consider an adversary who can eavesdrop on, tamper within the 5G core network, and we develop a slicing based solution.
● ZTX solution: Secure transport between *open5gs* core network functions so that confidentiality and integrity over service-based interfaces is guaranteed.

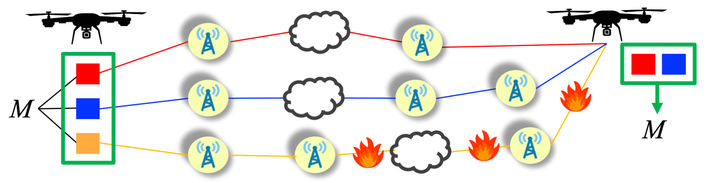
Jamming Resilience via Adaptive Frequency Hopping



● Utilizes existing 5G bandwidths and subcarriers to implement in-band Frequency Hopping.
● Exploits mandatory UE reporting of Signal-to-Interference-plus-Noise Ratio (SINR) to the gNB.
● Assigns subcarriers based on SINR.
● Offers improved resilience, faster throughput, and low complexity.

Preventive Mechanisms

Recovery from Unanticipated Attacks via Multipath Communication



● Defeats entire class of DoS attacks at a single relay.

Security Challenge: ● 5G systems vulnerable to evolving cyber threats
● Risk of denial-of-service attacks.

ZTX solution: ● A single relay cannot learn anything.
● Proactive rather than reactive design.
● No need to cooperate with network.

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