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Bretagne-Pays de la Loire
École Mines-Télécom

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Security Challenges for Underwater Acoustic Sensor Networks

Dmytro Ochkas, PhD Student

Directrice: Hélène LE BOUDER
Encadrant: Alexander PELOV

Content

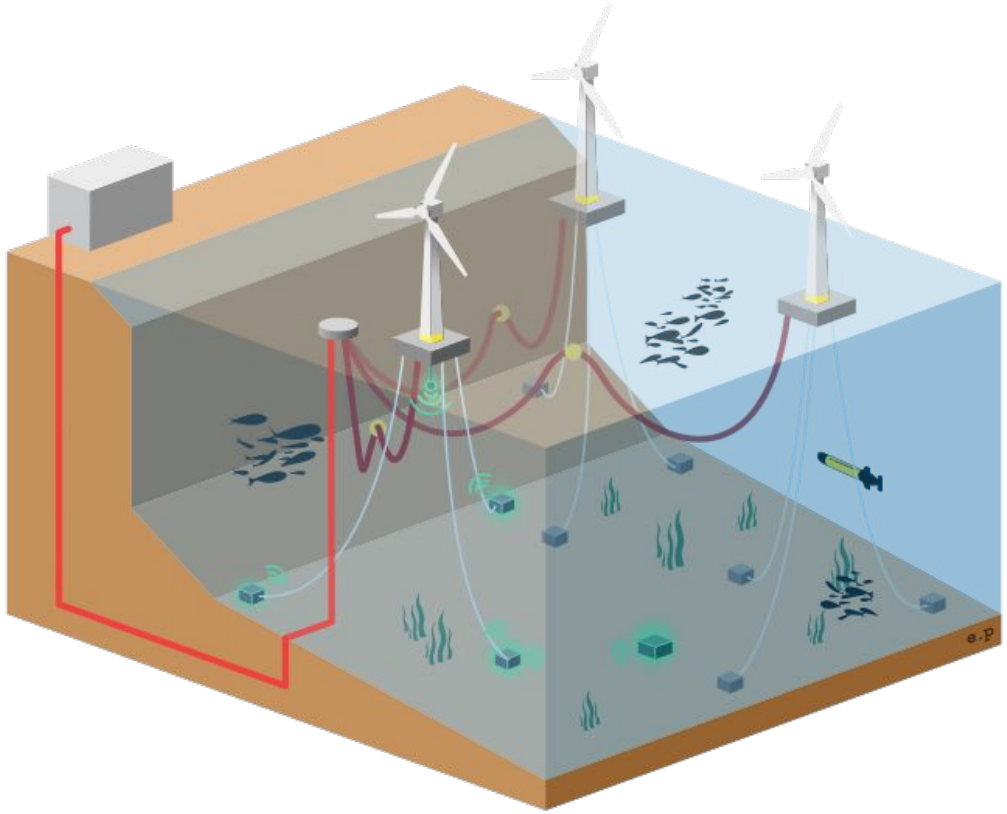
1. UASN - Underwater Acoustic Sensor Networks
   - 1.1. UASN Structure and Topologies
   - 1.2. UASN vs LPWAN
2. Security Challenges in UASN
   - 2.1. Security Properties
   - 2.2. Security Challenges
3. Attacks on UASN and Mitigation
   - 3.1. Jamming
   - 3.2. Eavesdropping
   - 3.3. Message Tampering
   - 3.4. Spoofing
   - 3.5. Replay
   - 3.6. Routing
4. Conclusion

CHAPTER 1

Underwater Acoustic Sensor Networks

UASN - Underwater Acoustic Sensor Networks

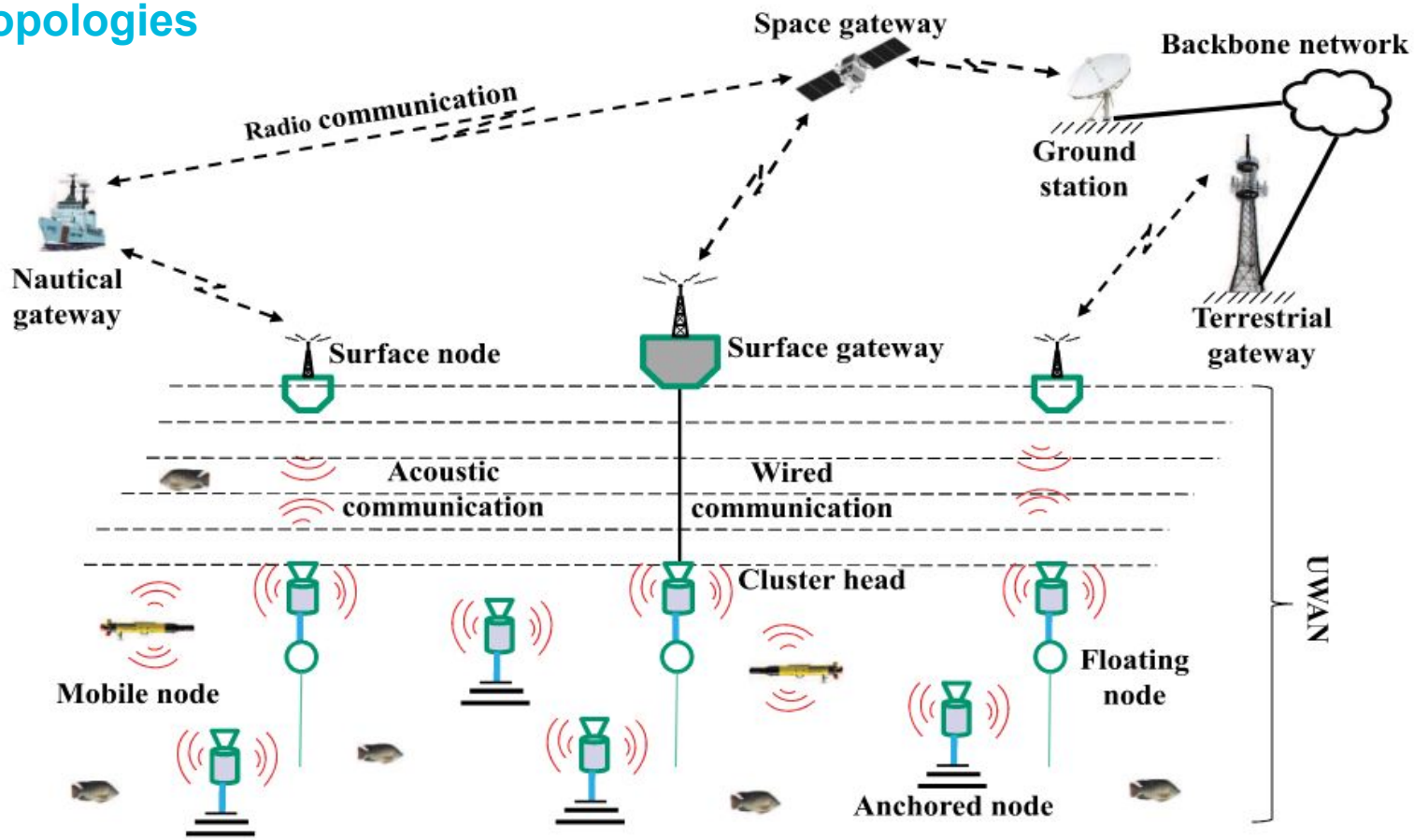
- Acoustic wave communication
- Sensor nodes, sink nodes, and terrestrial gateways
- Collecting data and transmitting it to the application server



UASN wind farm cable monitoring [1]

[1] Benoît Parrein, Fekher Khelifi, François Babin, Thierry Grousset, Jean-Marc Rousset, and Loïc Helloco. Underwater acoustic sensor network to monitor floating offshore wind: SEM-REV sea trials. In IEEE OCEANS, Limerick, Ireland, June 2023. URL https://hal.science/hal-04190985.

UASN Structure and Topologies

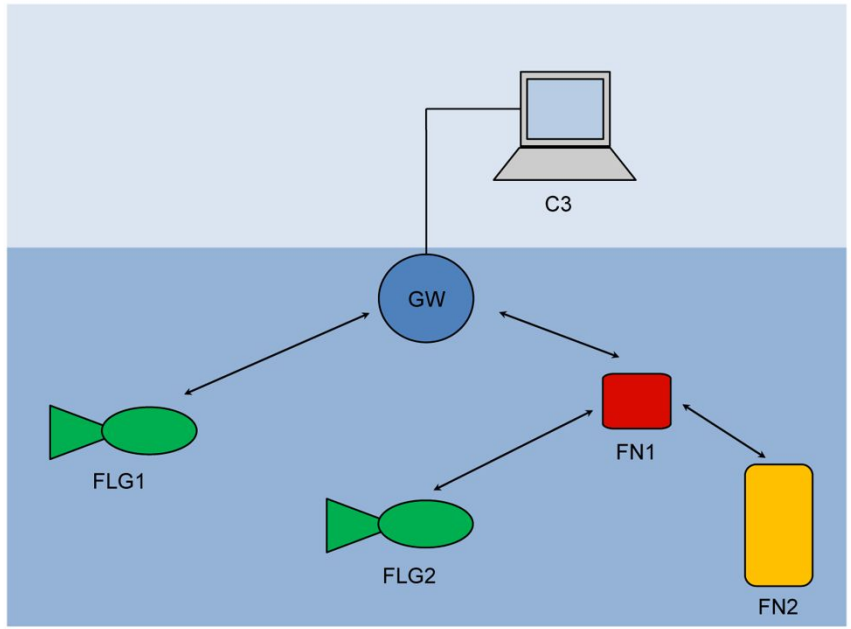


Source: S. Jiang, "On Securing Underwater Acoustic Networks: A Survey," in IEEE Communications Surveys & Tutorials, vol. 21, no. 1, pp. 729-752, Firstquarter 2019, doi: 10.1109/COMST.2018.2864127.

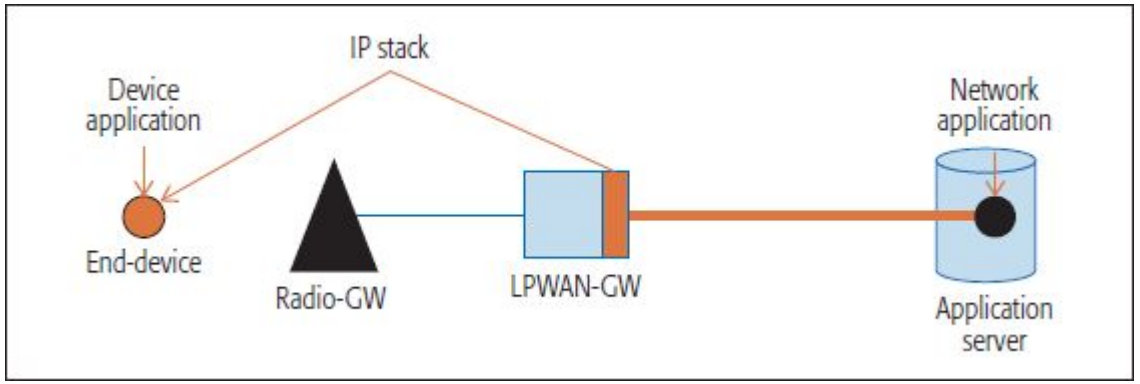
Underwater Acoustic Sensor Networks

UASN Structure and Topologies

UASN [1]



LPWAN [2]

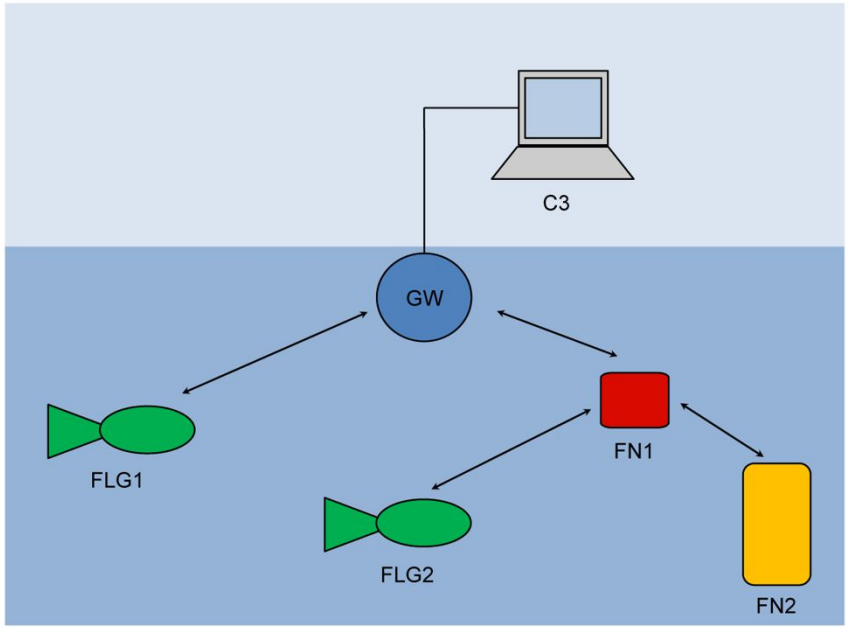


[1] Gianluca Dini and Angelica Lo Duca. A secure communication suite for underwater acoustic sensor networks. Sensors, 12(11):1513315158, 2012. ISSN 1424-8220. doi: 10.3390/s121115133. URL https://www.mdpi.com/1424-8220/12/11/15133

[2] Pascal Thubert, Alexander Pelov, and Suresh Krishnan. Low-power wide-area networks at the ietf. IEEE Communications Standards Magazine, 1(1):76–79, 2017. doi: 10.1109/ MCOMSTD.2017.1600002ST.

UASN Structure and Topologies

Multi-hop UASN [1]



FLG - AUV of Folaga type

FN - Fixed Node

C3 - Command and Control Center

[1] Gianluca Dini and Angelica Lo Duca. A secure communication suite for underwater acoustic sensor networks. Sensors, 12(11):1513315158, 2012. ISSN 1424-8220. doi: 10.3390/s121115133. URL https://www.mdpi.com/1424-8220/12/11/15133

Comparing UASN and LPWAN

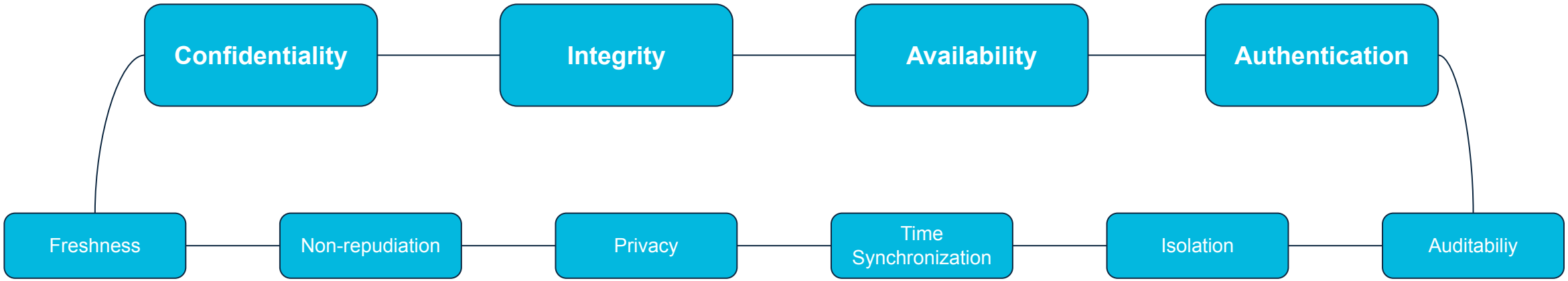
Criteria	UASN	LPWAN
Communication Type	Acoustic Wave	Electromagnetic Wave
Propagation Speed	~1500 m/s	~300,000,000 m/s
Bandwidth	few kHz	tens to hundreds of kHz
Range	Up to 30 km	Up to 15 km
Autonomy	1-6 months	1-10 years
Reliability	Highly unreliable (multipath, absorption, Doppler effect, scattering, noises)*	Moderate (multipath, scattering)
Bit Rate	~1 kbits/s	0.1 - ~100 kbits/s

CHAPTER 2

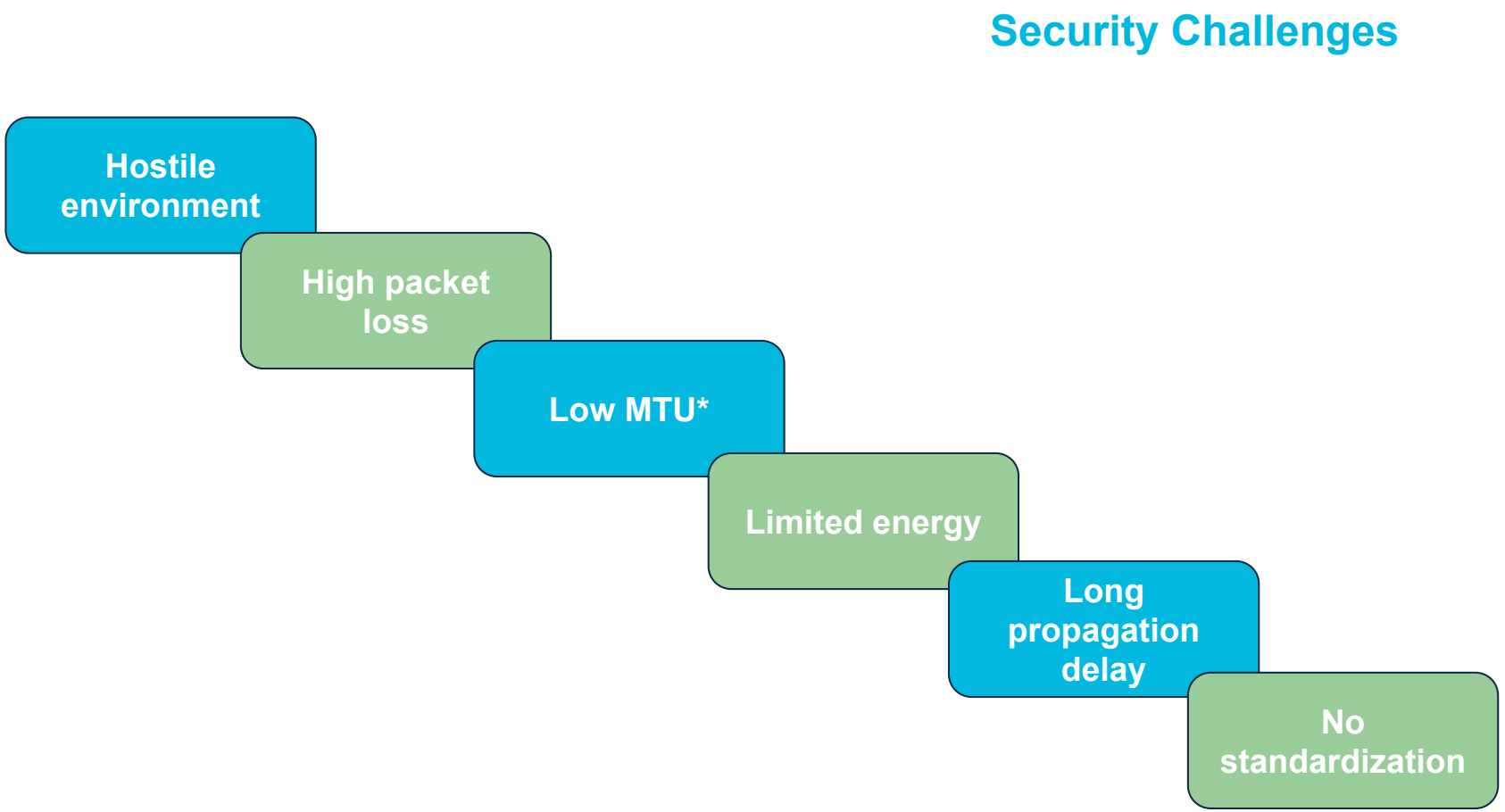
Security Challenges in UASN

Security Challenges in UASN

Security Properties



Security Challenges in UASN



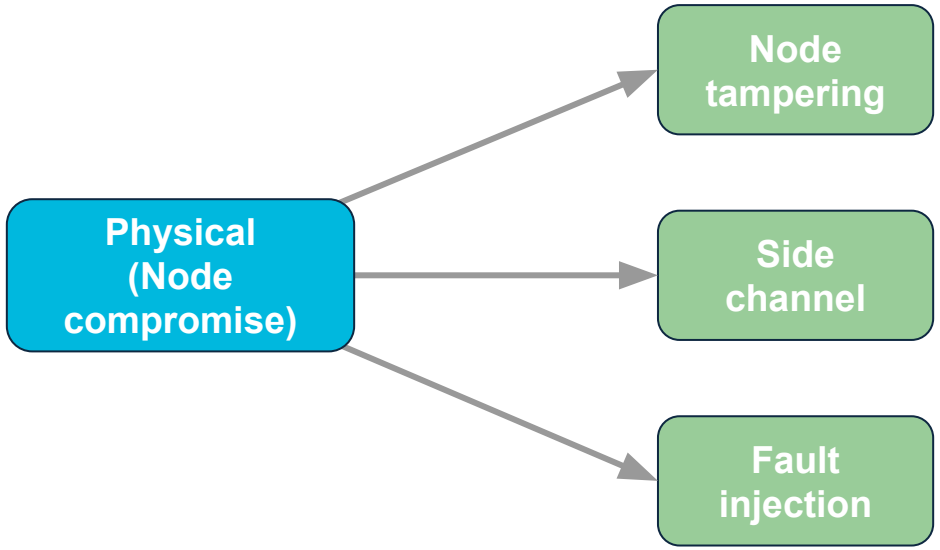
* MTU - Maximum Transmission Unit

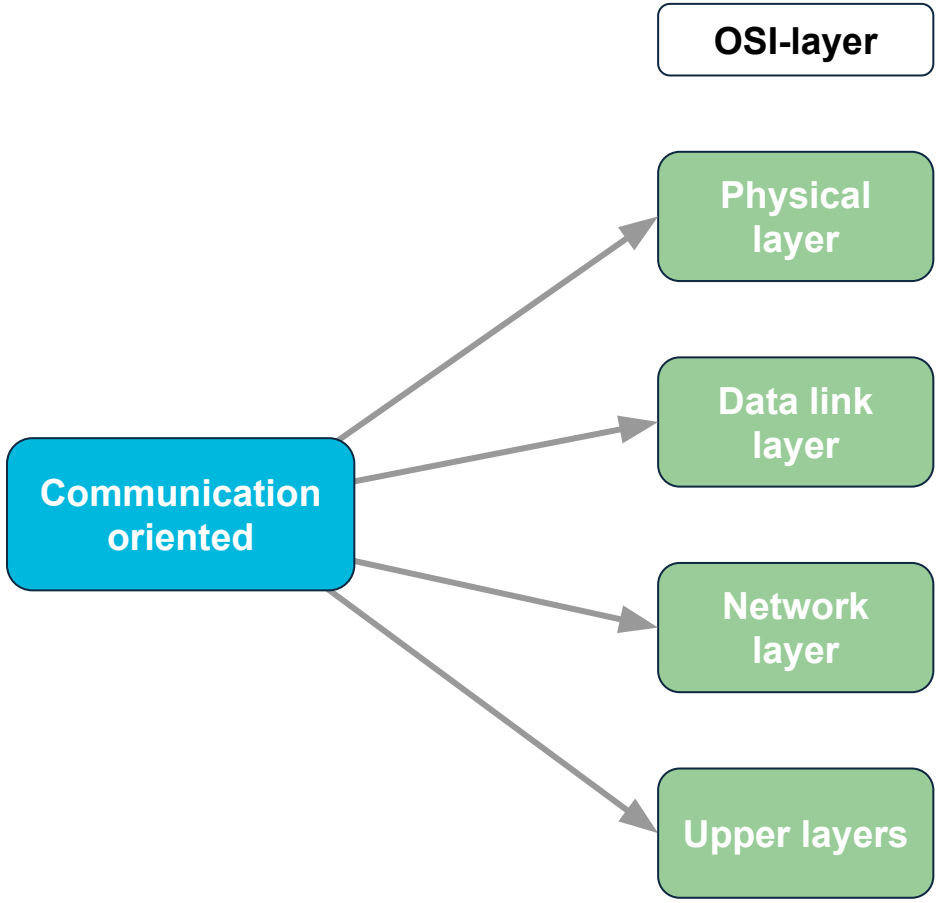
CHAPTER 3

Attacks on UASN and Mitigation

Attacks on UASN

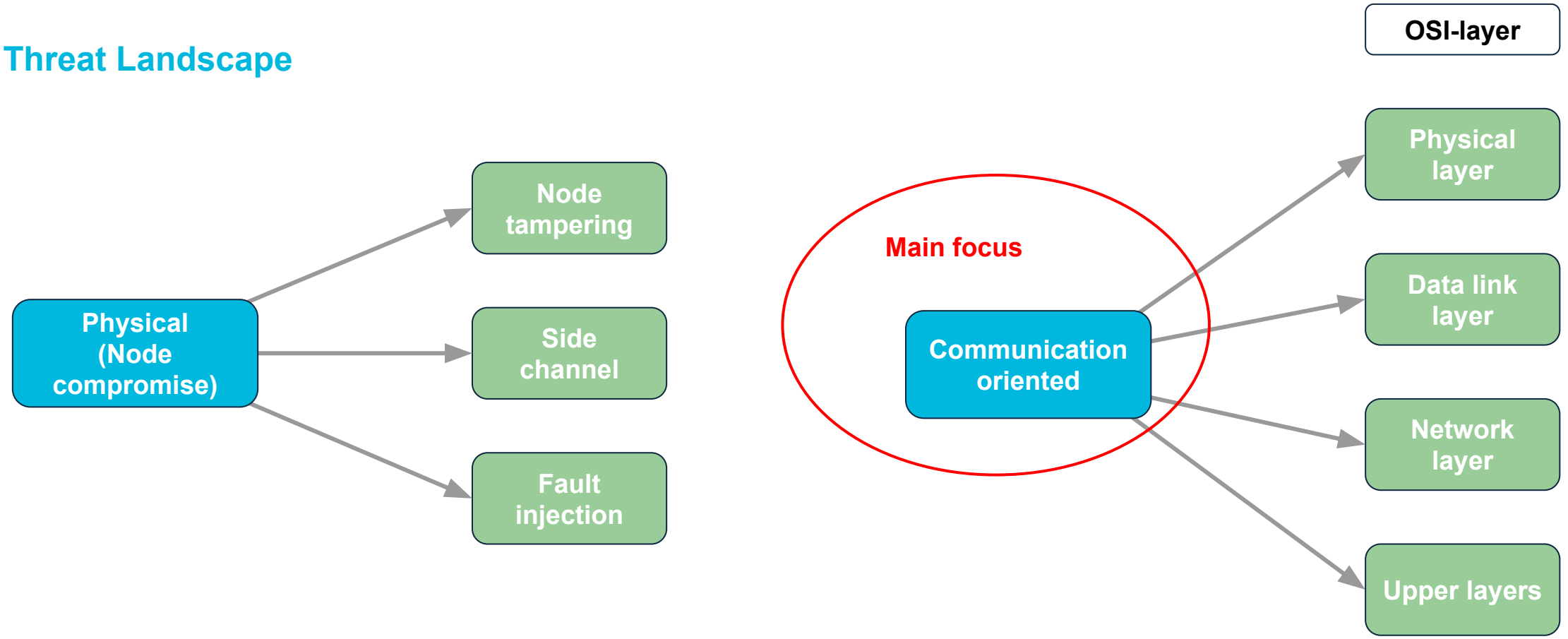
Threat Landscape





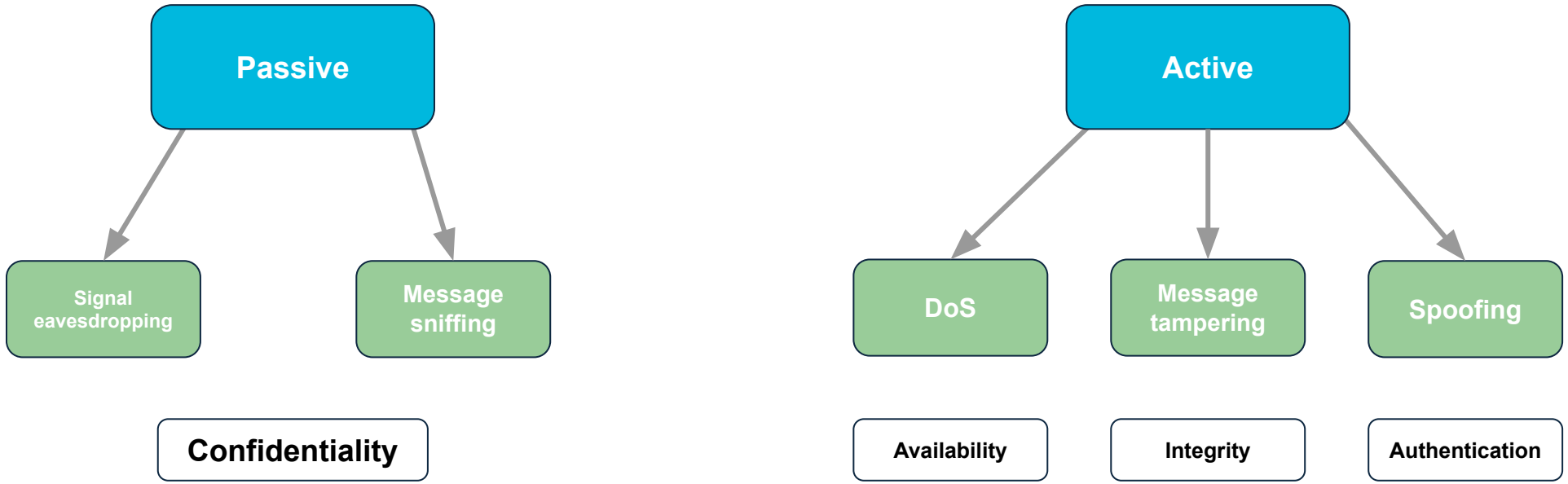
Attacks on UASN

Threat Landscape

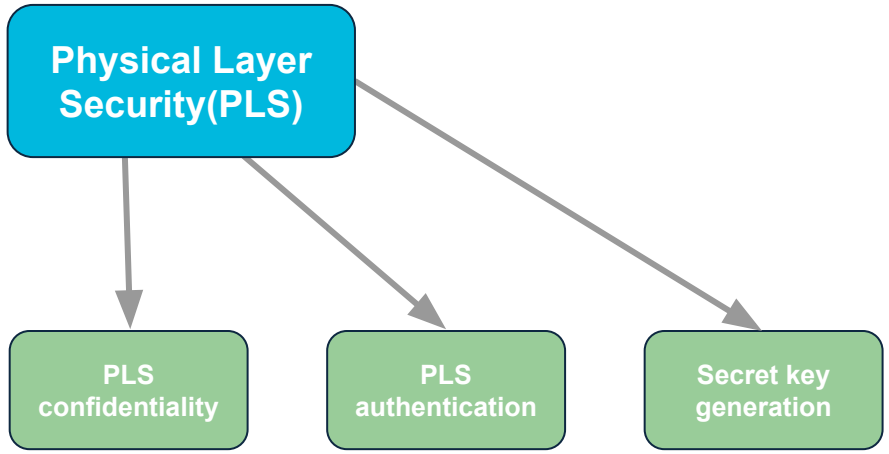


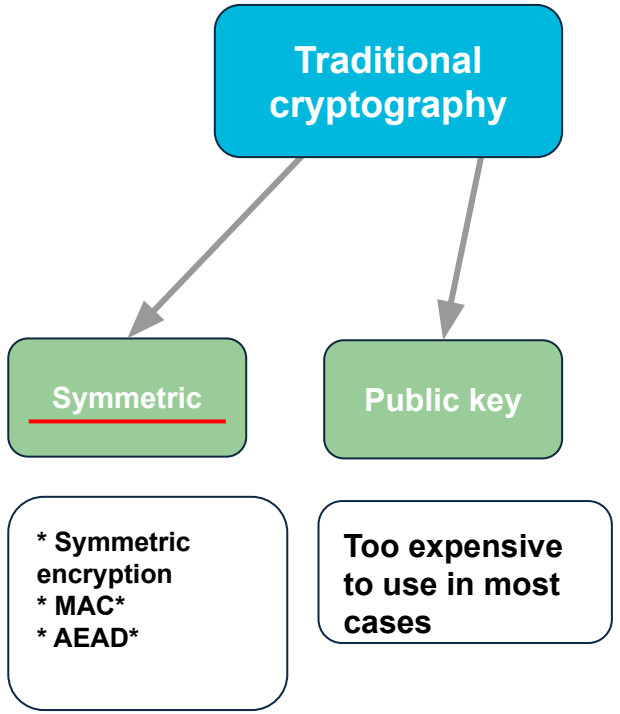
Attacks on UASN

Threat Landscape



UASN Security Strategies



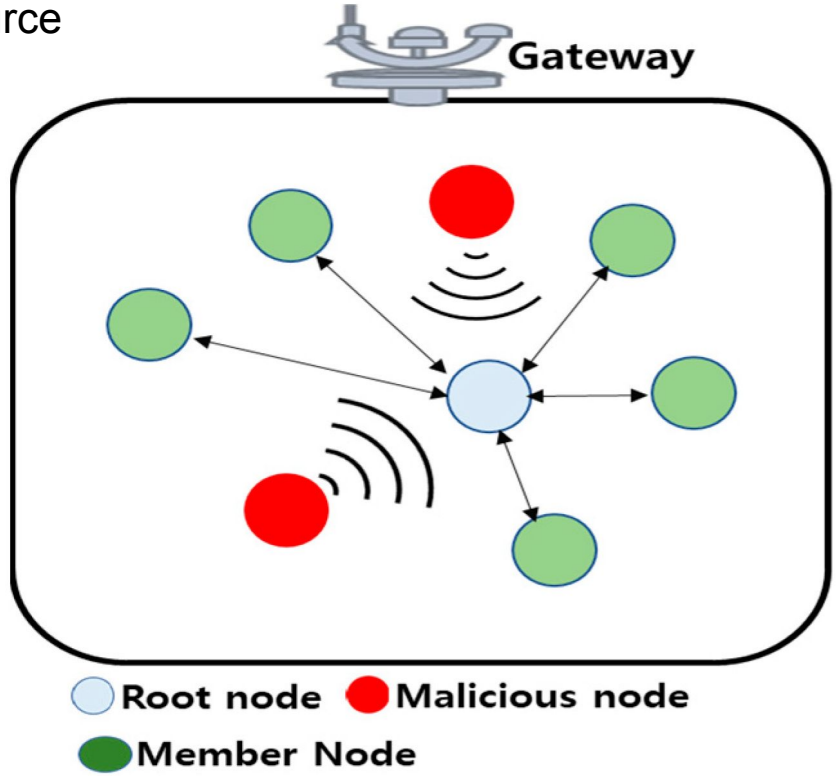


MAC - Message Authentication Code (authentication tag
AEAD - Authenticated Encryption with Associated Data)

Attacks on UASN

Jamming

Put source



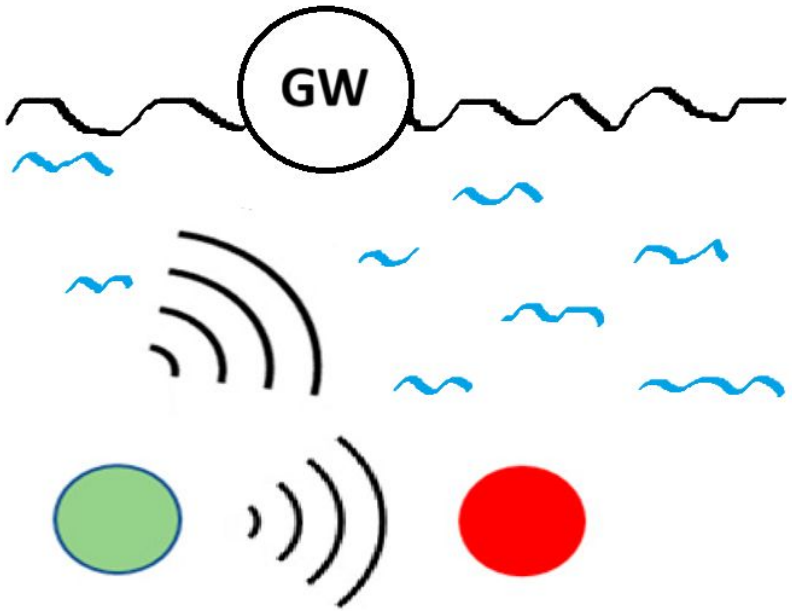
Mitigation

- Obscuring the communication
- Constant network monitoring for anomalies:
  - high packet loss
  - high signal strength with low throughput
  - frequent retransmissions
- Switching to another frequency
- Shutdown for a certain period

Source: Delphin Raj Kesari Mary, Eunbi Ko, Seung-Geun Kim, Sun-Ho Yum, Soo-Young Shin, and Soo-Hyun Park. A systematic review on recent trends, challenges, privacy and security issues of underwater internet of things. Sensors, 21(24), 2021. ISSN 1424-8220. doi: 10.3390/s21248262.

Attacks on UASN

Eavesdropping



Types

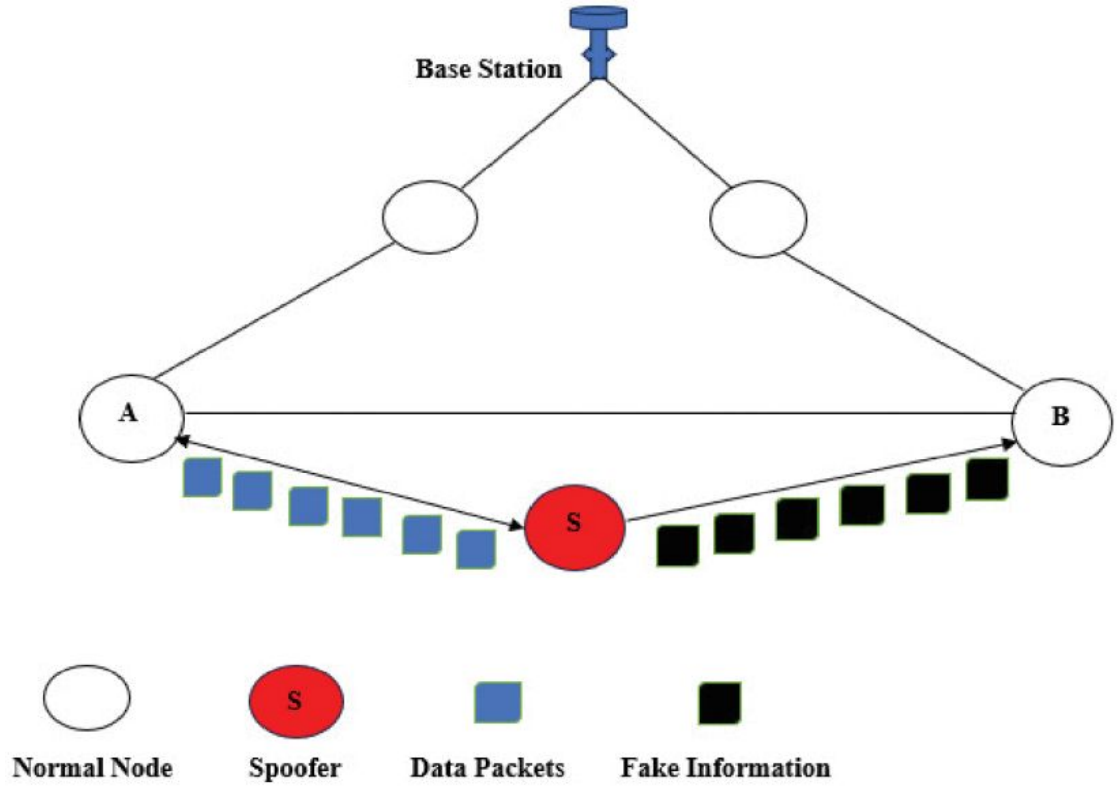
- Signal eavesdropping
- Message sniffing
- Traffic analysis

Mitigation

- Physical layer confidentiality
- Lightweight encryption

Attacks on UASN

Message Tampering



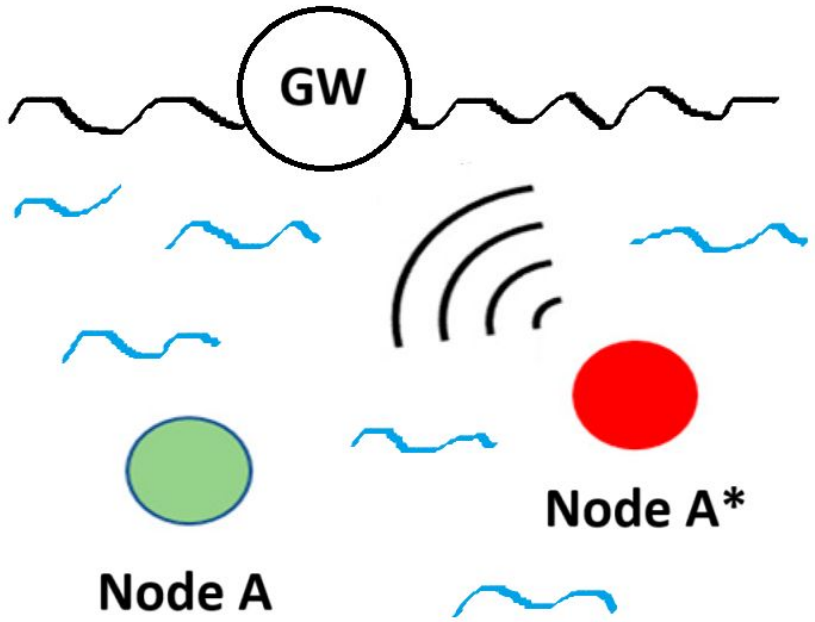
Mitigation

- Integrity
- Authentication tag, usually truncated to 2, 4, 8 bytes

Source: K. Masood Ahmed, R. Shams, F. H. Khan and M. -Á. Luque-Nieto, "Securing Underwater Wireless Sensor Networks: A Review of Attacks and Mitigation Techniques," in IEEE Access, vol. 12, pp. 161096-161133, 2024, doi: 10.1109/ACCESS.2024.3490498.

Attacks on UASN

Spoofing

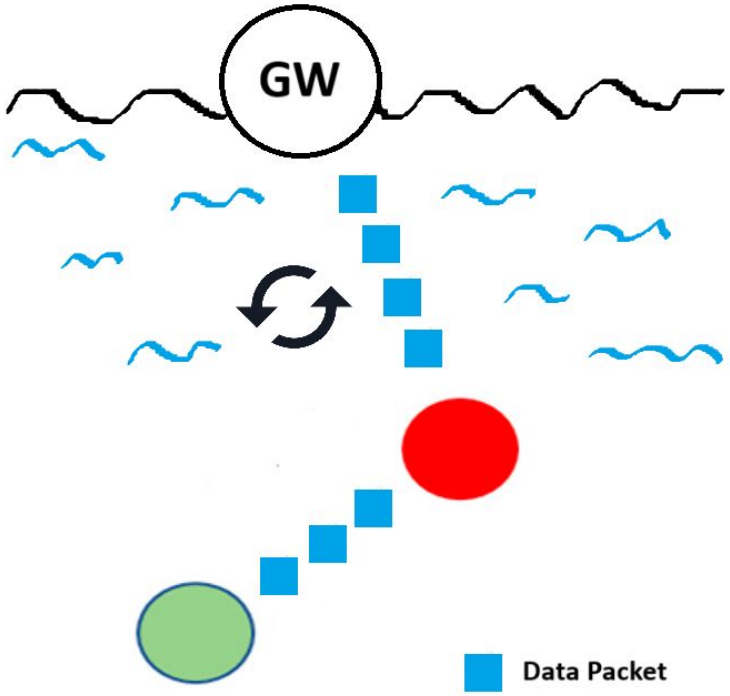


Mitigation

- Reliable authentication mechanism
- Initial handshake (too expensive)
- Node identification mechanism
- Authentication tag

Attacks on UASN

Replay



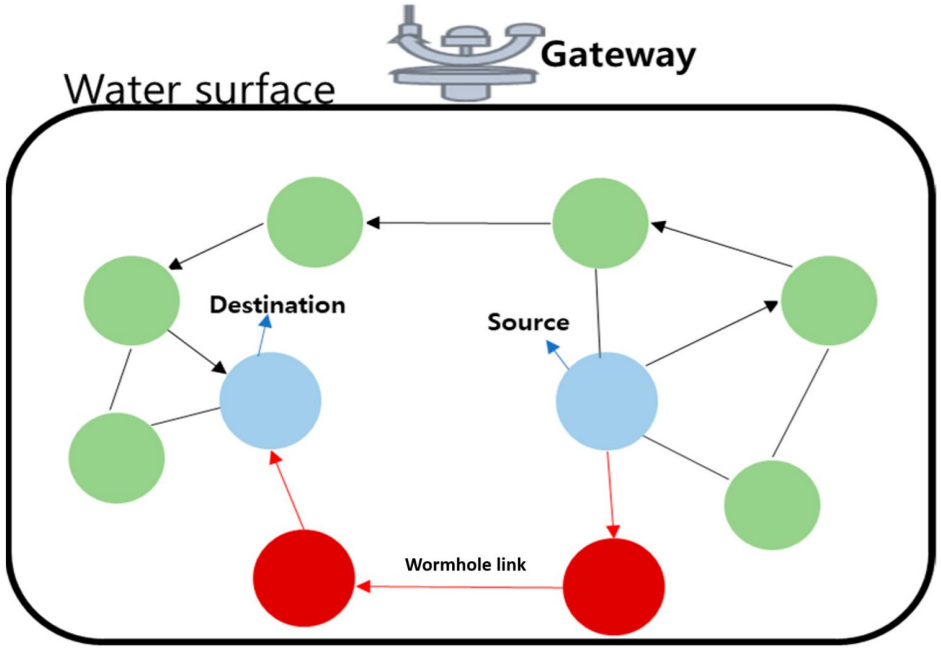
Mitigation

- Message ID
- Effective nonce usage, e.g., with timestamp

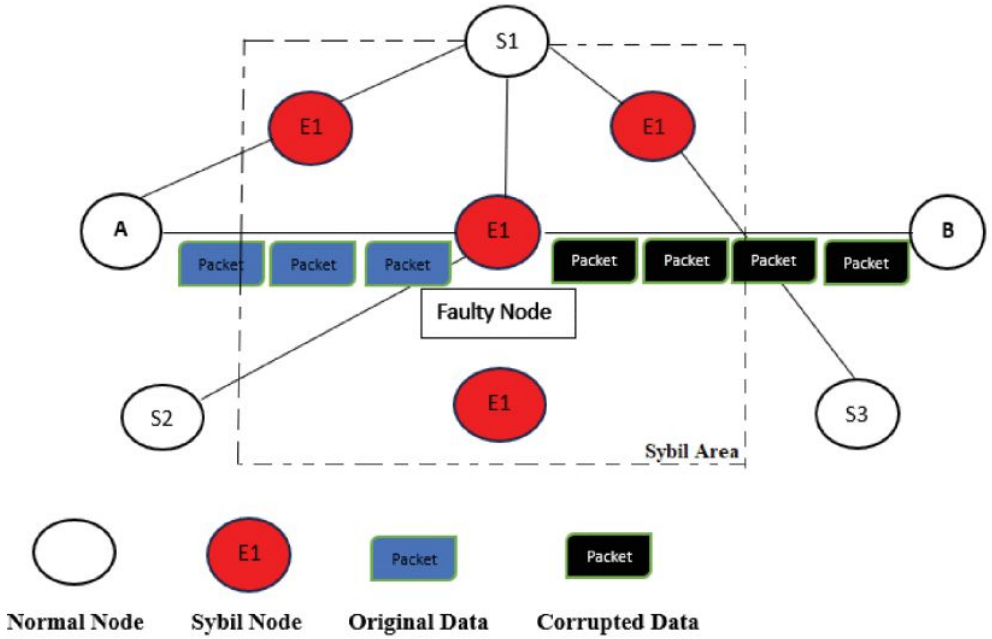
Attacks on UASN

Routing

Wormhole [1]



Sybil [2]



[1] Delphin Raj Kesari Mary, Eunbi Ko, Seung-Geun Kim, Sun-Ho Yum, Soo-Young Shin, and Soo-Hyun Park. A systematic review on recent trends, challenges, privacy and security issues of underwater internet of things. Sensors, 21(24), 2021. ISSN 1424-8220. doi: 10.3390/s21248262.

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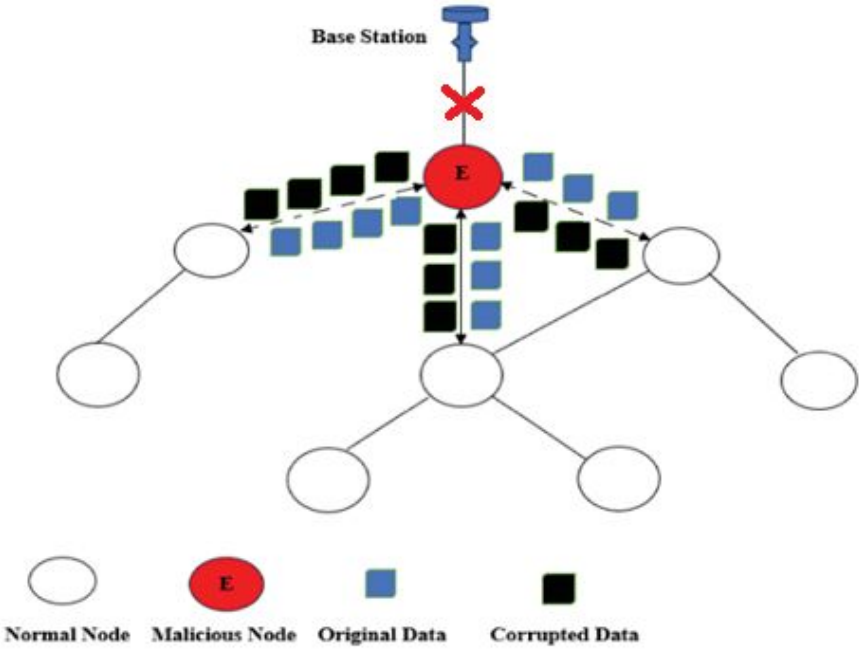
Attacks on UASN

Routing

Blackhole [1]



Mitigation

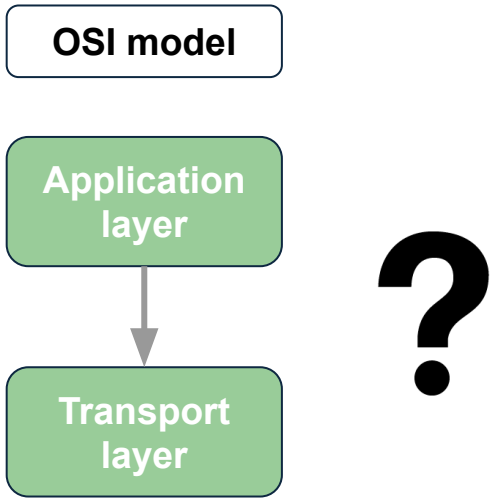
- Spoofing protection
- Secure localization
- Node isolation

[1] K. Masood Ahmed, R. Shams, F. H. Khan and M. -Á. Luque-Nieto, "Securing Underwater Wireless Sensor Networks: A Review of Attacks and Mitigation Techniques," in IEEE Access, vol. 12, pp. 161096-161133, 2024, doi: 10.1109/ACCESS.2024.3490498.

Attacks on UASN

As for upper layer attacks…

- Lack of standardization
- As of today, poorly investigated



Conclusion

- Acoustic networks remain the main way of underwater communication despite the hostile environment.
- UASN have a lot of similarities with LPWAN but the conditions are even more restrictive and multi-hop communication is widely adopted.
- Threat landscape is large and the new attacks keep occurring even today.
- Research effort should continue to create an efficient lightweight security model for UASN.

Literature

[1] Benoît Parrein, Fekher Khelifi, François Babin, Thierry Grousset, Jean-Marc Rousset, and Loïc Helloco. Underwater acoustic sensor network to monitor floating offshore wind: SEM-REV sea trials. In IEEE OCEANS, Limerick, Ireland, June 2023. URL https://hal.science/hal-04190985.

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Dmytro Ochkas

Email: dmytro.ochkas@imt-atlantique.fr