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An Experimental Performance Assessment of Galileo OSNMA

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ESRIUM project background

- Work done in Horizon2020 funded project ESRIUM
- Goal: create road-wear map with accurate information about the position and shape of the road damage
- Sensor vehicle with LiDARs (road damage estimation) and GNSS (positioning)
- Galileo is used for positioning the sensors vehicle, Galileo OSNMA is used increase the security and robustness of the solution
    - Therefore practical understanding of OSNMA characteristics was important for us

ESRIUM

SAFE AND EFFICIENT ROADS

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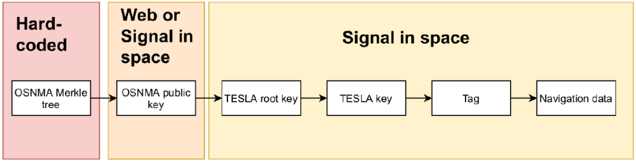
The shortest intro to Galileo OSNMA

- OSNMA = Open Service Navigation Message Authentication
  - Goal is to verify that the received satellite data is both authentic and unmodified
- Variety of well tested cryptographic methods adapted to the satellite data use case are used to achieve this
  - Keys to authenticate the navigation data are transmitted in the signal-in-space
  - Key and navigation data are used to compute a tag: received tag and computed tag are compared
  - Keys form a hash chain: enables the verification that the key is coming from the same source as the previous
  - Public key cryptography is used to verify the first chain key (= root key)
  - The public keys are verified by a Merkle tree



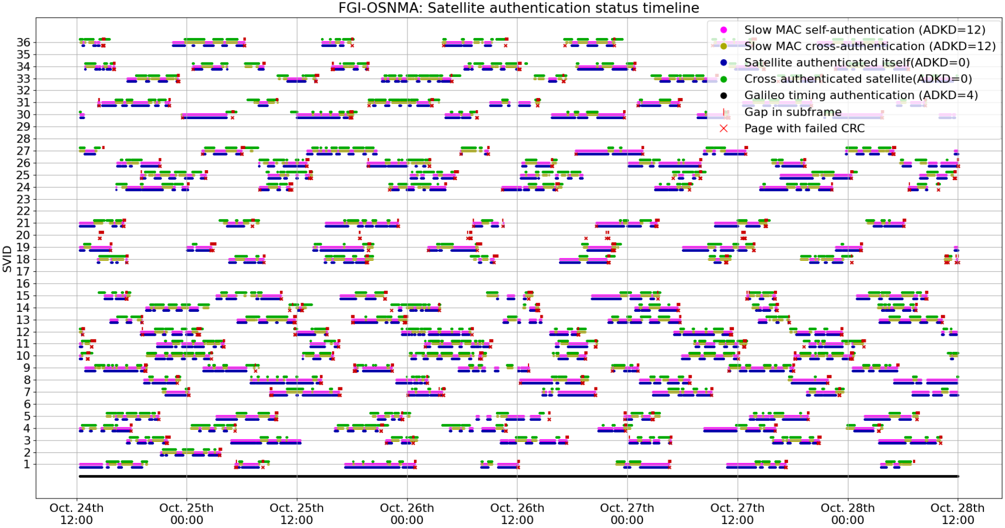
Experimental setup

- Data collection in static open sky condition during 24.10-28.10 in Espoo, Southern Finland
  - Approximately 95h of data
  - Represents best case scenario
- Septentrio Mosaic X5 receiver
  - The Galileo raw navigation bits can be obtained from this receiver, which enables OSNMA processing
- All of the processing has been done by our own OSNMA implementation, tentatively named FGI-OSNMA

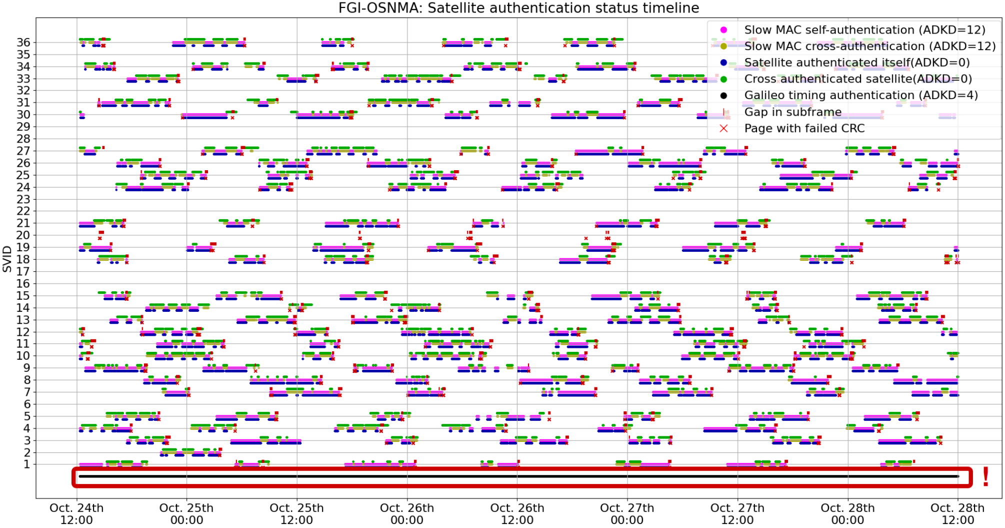
FGI-OSNMA

- Written in Python, made with special emphasis on modularity, and usability in real-time, and integrability as a library in third-party applications
- Validated with the so-called test vectors published by EUSPA, and by comparing the results to other available OSNMA implementation, such as OSNMAlib
- Will be made open-source in the near future

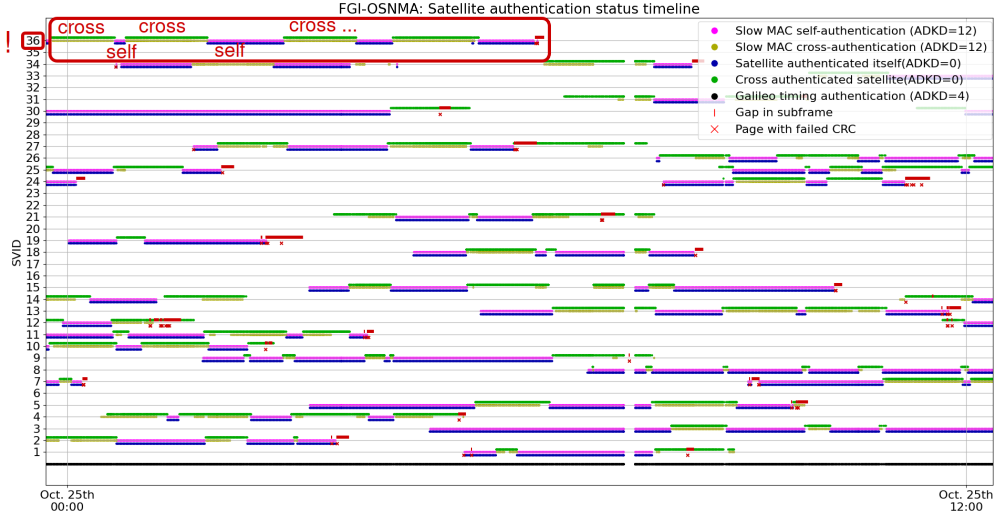
Results: authentication and data transmission events visualized



Galileo constellation timing data (ADKD=4) authentication



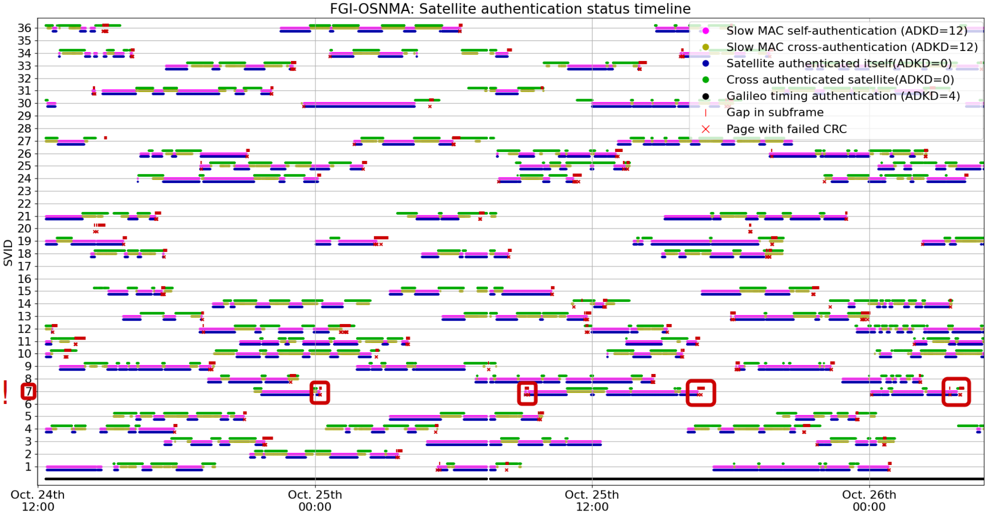
Alternation between self-authentication and cross-authentication


FGI-OSNMA: Satellite authentication status timeline

Satellite elevation and CRCs

- Satellite elevation is very visible in the timeline: when a satellite reaches low elevation, there will be data reception problems, and the receiver will receive pages with failed CRCs, and hence there will be gaps in the subframes
- Shortly after the data reception problems the satellite vanished below the horizon, hence it will no longer be authenticated or even visible
- Data reception problems from low elevation satellites is widely known, and similar behavior can be expected in any satellite application, this is not specific to OSNMA

Satellite elevation and CRCs



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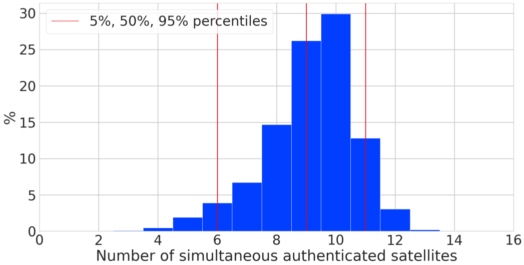
Statistics related to authentication

Statistic	Value
Simultaneous authenticated satellites: 5% percentile	6
Simultaneous authenticated satellites: average	9.14
Simultaneous authenticated satellites: 95% percentile	11
Percentage of authenticated fixes	99.74%
Self-authentications out of all ADKD=0 authentications	37.91%
Cross-authentications out of all ADKD=0 authentications	62.09%

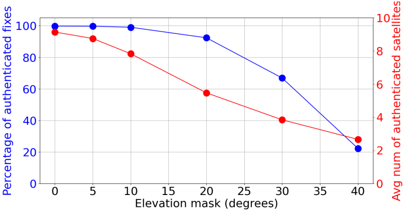


KPIs as a function of the elevation mask

- Previous results are excellent, but they represent the best case scenario (= static open sky)
- How does satellite visibility effect the results?
  - We apply an elevation mask to OSNMA processing: the OSNMA engine is run, but the data from satellites below the elevation mask is discarded
    - This approximates situations with limited satellite visibility. For example, buildings in urban areas block signals $\implies$ higher elevation mask

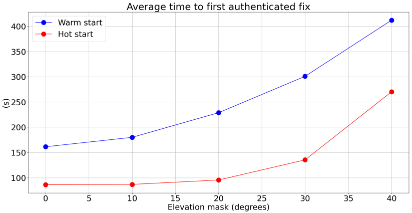
KPIs as a function of the elevation mask

Elevation mask	**Number of authenticated fixes**	**Authenticated sats. count Percentiles: 5%, 50%, 95%**
0°	99.74%	6, 9, 11
5°	99.66%	6, 9, 11
10°	99.0%	5, 8, 10
20°	92.33%	3, 6, 8
30°	66.83%	2, 4, 6
40°	22.24%	0, 3, 4



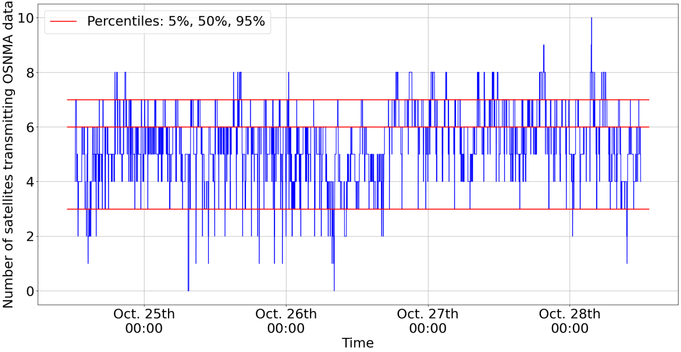
Time to first authenticated fix as a function of the elevation mask

Elevation mask	**Warm-start (Percentiles: 10%, 50%, 90%)**	**Hot-start (Percentiles: 10%, 50%, 90%)**
0°	104, 150, 232	74, 86, 98
10°	116, 166, 262	74, 86, 98
20°	136, 208, 338	74, 88, 116
30°	168, 262, 424	78, 102, 152
40°	200, 318, 570	86, 128, 454



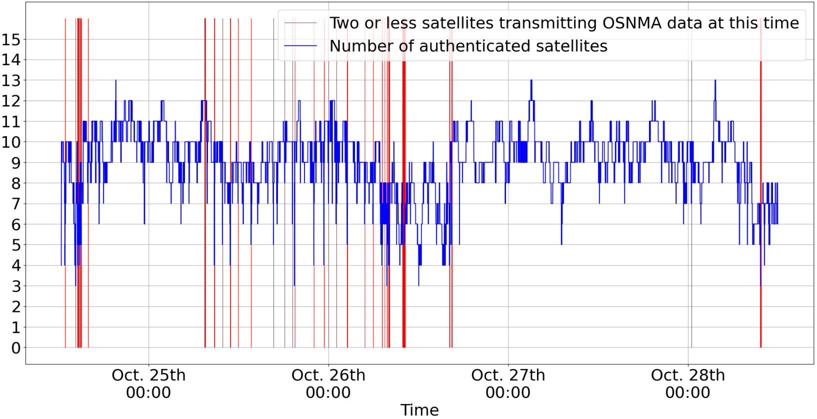
What happens in situations where we fail to get authenticated fixes?

- In our dataset the problem is that occasionally there are very few visible satellites transitting OSNMA data
  - Little to no OSNMA data $\Longrightarrow$ Very few tags $\Longrightarrow$ Very few authentications $\Longrightarrow$ Unable to get authenticated fix



Correlation of OSNMA data transmission and number of authentications

- Very few satellites transmitting OSNMA data (red lines) ⟹ Drop in the number of authenticated satellites (blue line)



Observations and conclusion

- OSNMA performance is good, satellite visibility can affect this greatly
- Only challenge during this test campaign was the occasional low number of satellites transmitting OSNMA data
  - OSNMA is still in its test phase: this can be improved in the future
- Cross-authentication has many benefits (redundancy, robustness)
  - Each satellite is responsible for authenticating multiple satellites $\Longrightarrow$ dropping one of these authenticating satellites (for example due to poor signal reception quality) can lower the amount of authenticated satellites significantly $\Longrightarrow$ this can be a difference between authenticated fix and a non-fix
    - This explains the elevation mask test results: elevation mask can make you drop satellites these authenticating satellites
    - It is common to apply an elevation mask when calculating positions, however, no mask should be applied to OSNMA data reception

Thank you for your interest!

- Questions?