Security fundamentals and ROS security

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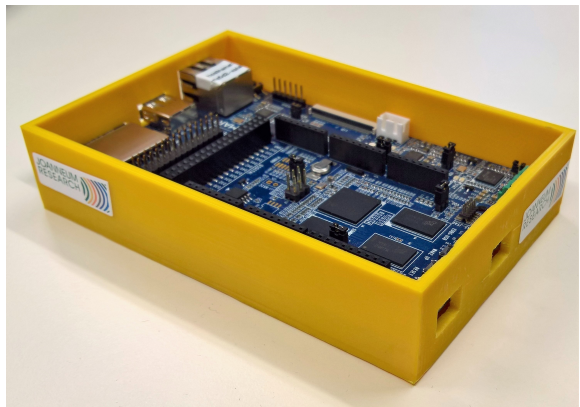
Institute for Robotics and Mechatronics

- Founded 2015
- Focus on industrial robotics and mechatronics
- `https://www.joanneum.at/robotics`

- 45 researchers in 2021 in 3 groups
  - Mechatronic Systems
  - Robot Systems
  - Cognitive Robotics



[Taurer et al., 2018]

Cyber threats in robotics

- Classically, robots have worked in isolation
- Modern robots work in highly interconnected environments
- Industry-grade robots are not harmless machines
- Robots pose risks to property and life
- Insecure robots may be manipulated remotely
- Industrial security is breached frequently [Byres et al., 2004, Cheminod et al., 2013, Stouffer et al., 2015, Karnouskos, 2011, Nelson, 2016, Fairley, 2016]

CIA+: The security objectives

- Confidentiality
  - Only the intended recipients can read data
  - Hide the contents of messages from third-party observers
  - Enabled by: **Encryption**
- Integrity
  - Prevent data from being tampered/modified by a third party
  - Prevent spoofing/masquerading and the so called "man in the middle" attacks
  - Enabled by: **Integrity checks, hashes**
- Authenticity
  - A given entity's claimed identity can be proven
  - Enabled by: **Certificates, digital signatures**
- Availability
  - Ensure that the system is working within defined boundaries

CIA priorities

In production, the priorities are reversed compared to the classical office environment. Availability is key!

Prio	**Office environment**	**Production environment**
1	Confidentiality	Availability
2	Integrity	Integrity
3	Availability	Confidentiality

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ROS1 security issues

- ROS has no built-in security [McClean et al., 2013]
- Missing authentication, authorization and confidentiality functions
- ROS is an easy target
  - Exploit XMLRPC-API
  - Use stealth publisher attack to inject data or isolate subscribers
  - Use service isolation for DoS
  - Use malicious parameter attack to manipulate parametrization for individual nodes

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Master API[1]

- XMLRPC API to interact with ROS master
- Enables discovering publishers and services
- *getSystemState* → get overview of whole network
- *lookupNode* → get URI of specific node
- *lookupService* → get URI of specific service
- *register*{*Subscriber*,*Publisher*} → subscribe, advertise
- *unregister*{*Subscriber*,*Publisher*} → unsubscribe, unadvertise
- **No authentication/authorization**

[1] http://wiki.ros.org/ROS/Master_API

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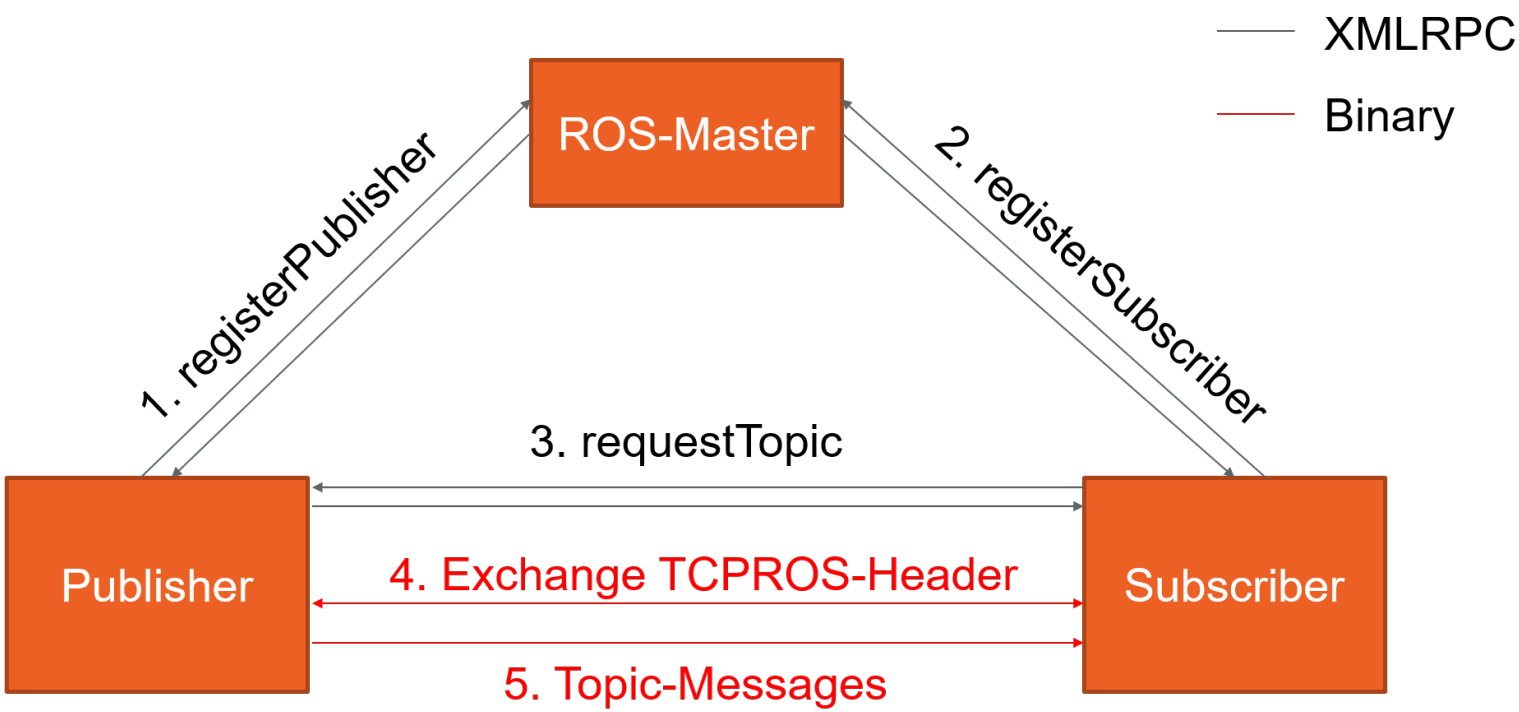
Node API[2]

- Communication mainly node2node (some Master→Node calls)
- *publisherUpdate* → send update on available publisers
- *requestTopic* → perform subscription
- *paramUpdate* → send new parameter server values
- *shutdown* → kill node
- **No authentication/authorization**
- After XMLRPC-handshake, topic communication is done using a binary wire protocol (unencrypted)

[2] http://wiki.ros.org/ROS/Slave_API

Communication structure in ROS



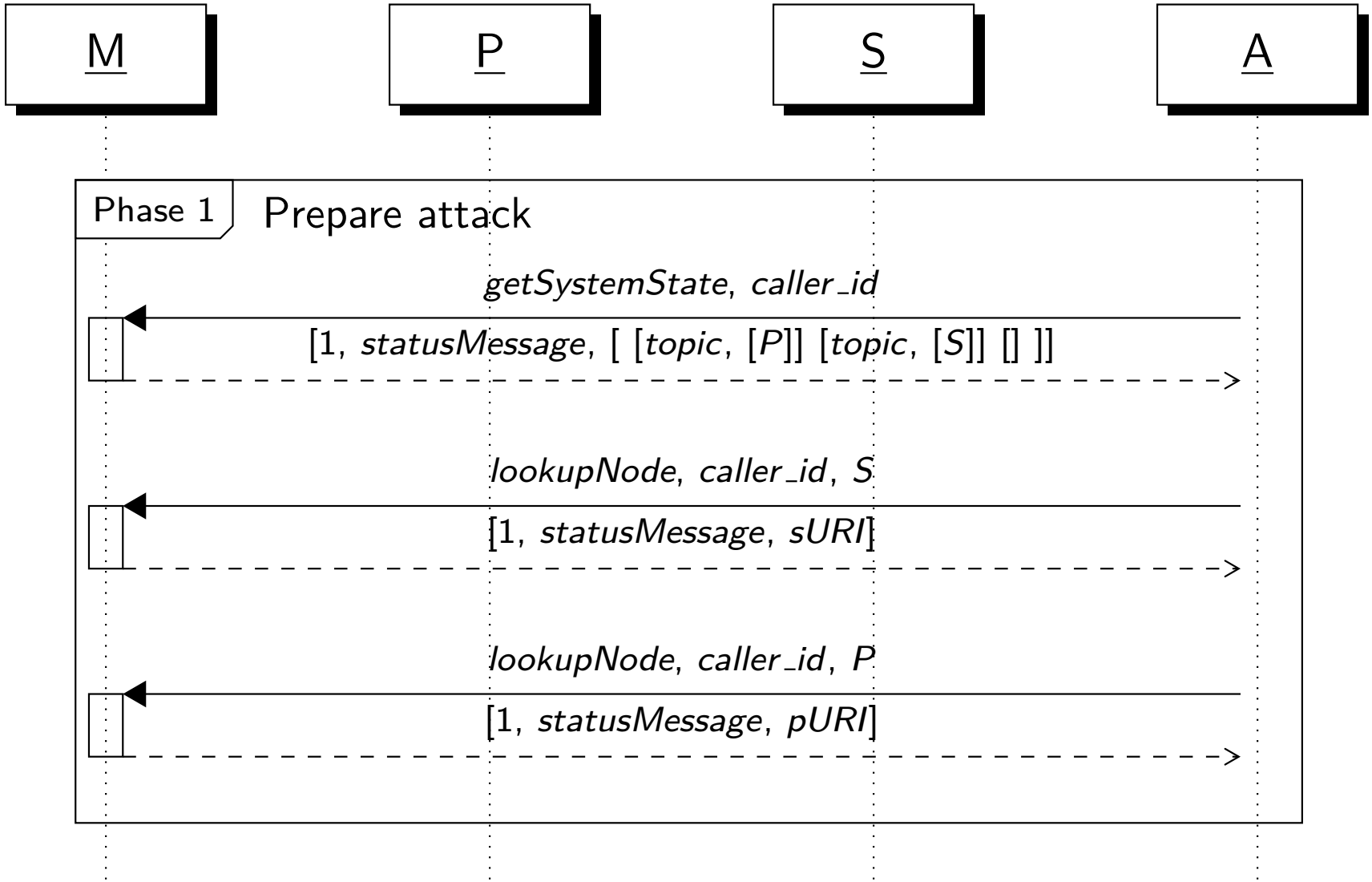
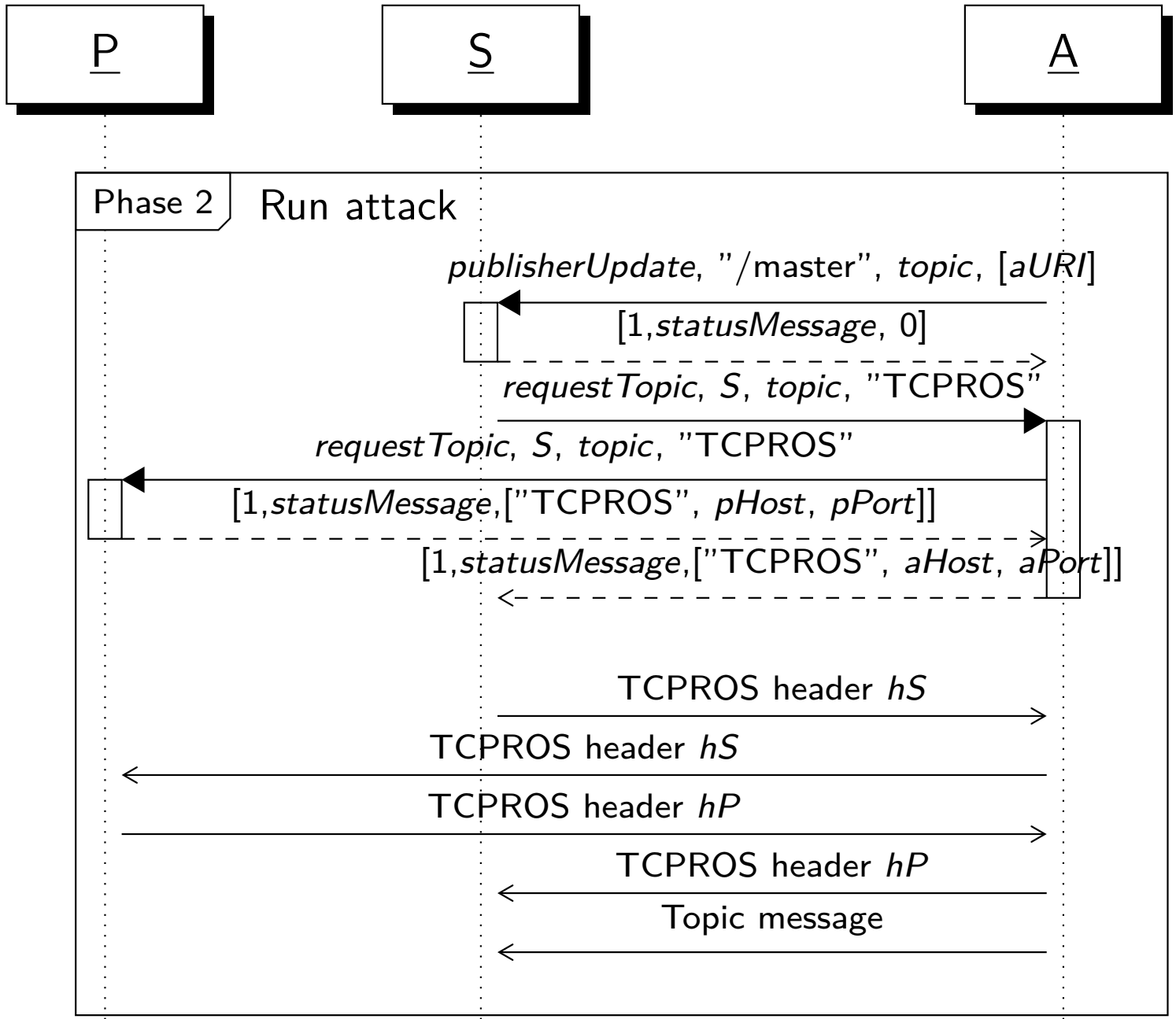


Figure: Sequence diagram of a Stealth Publisher Attack


P
S
A
Phase 2
Run attack
publisherUpdate, "/master", topic, [aURI]
[1,statusMessage, 0]
requestTopic, S, topic, "TCPROS"
requestTopic, S, topic, "TCPROS"
[1,statusMessage,["TCPROS", pHost, pPort]]
[1,statusMessage,["TCPROS", aHost, aPort]]
TCPROS header hS
TCPROS header hS
TCPROS header hP
TCPROS header hP
Topic message

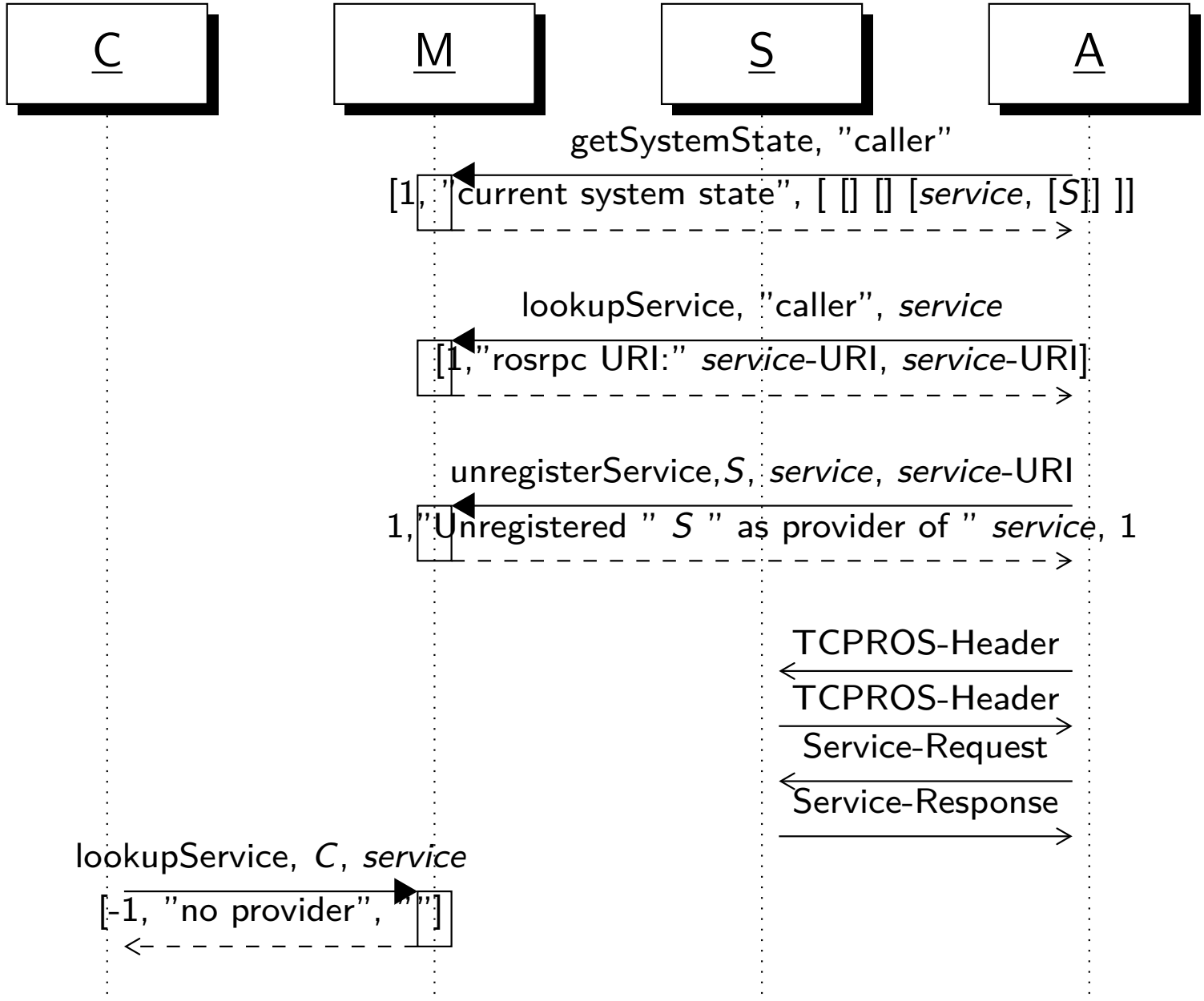


Figure: Sequence diagram of a Service Isolation Attack

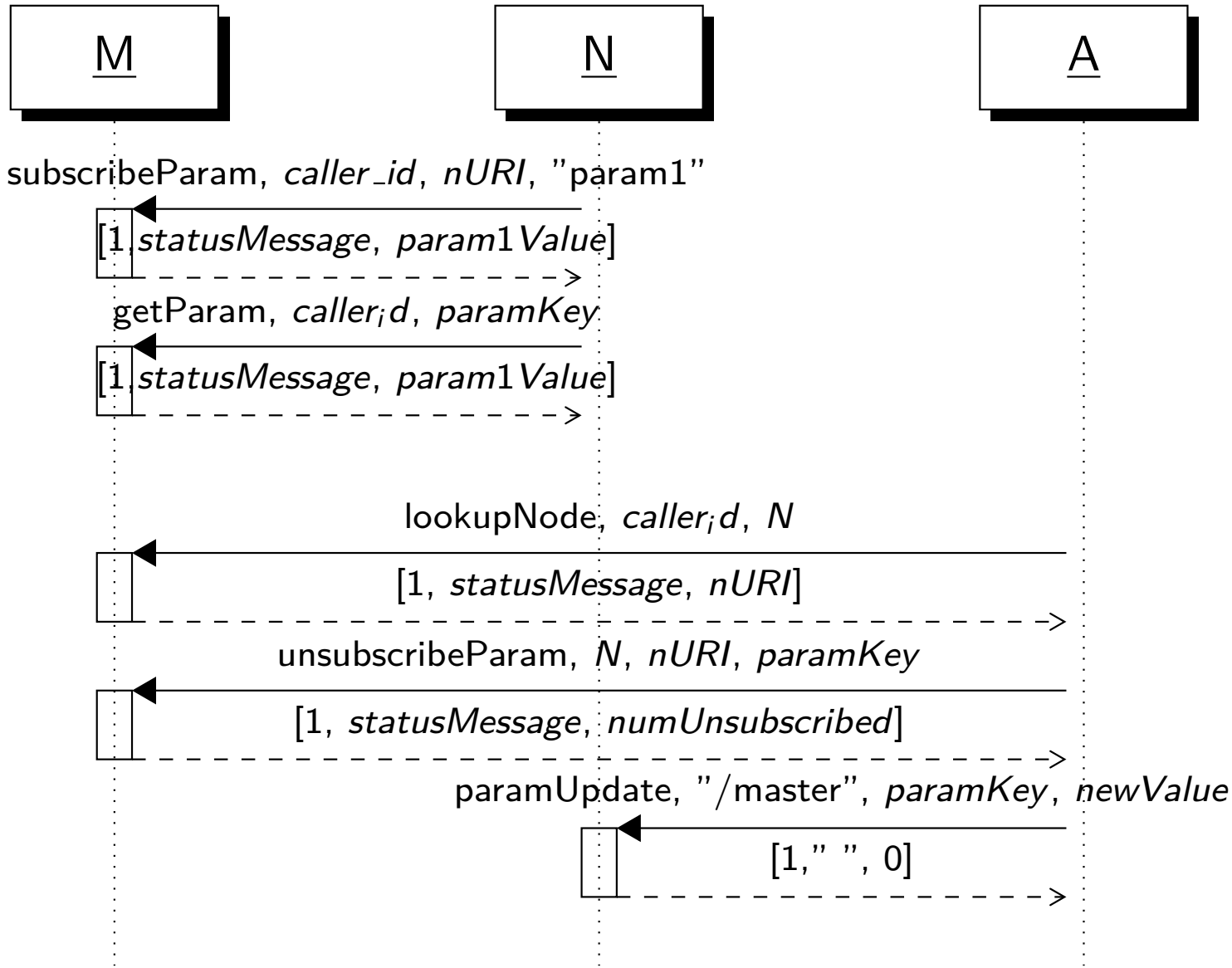


Figure: Sequence diagram of a malicious parameter update attack

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Some Videos

- Disabling safety functions
- Disturbing a MiR robot

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ROSPenTo

- Penetration testing tool for ROS
- `https://github.com/jr-robotics/ROSPenTo`
- Analyze multiple ROS networks
- Reroute communication
- Isolate services
- Manipulate parameters
- Alternative: roschaos
- Countermeasures: [Dieber et al., 2017, White et al., 2016], `http://secure-ros.csl.sri.com/`
- Video

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