Lightweight and Flexible Trust Assessment Modules for the Internet of Things

Jan Tobias Mühlberg, Job Noorman and Frank Piessens

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QA&Test @ Bilbao, October 2015

COSIC and DistriNet: Who we are.

COSIC (Bart Preneel, Ingrid Verbauwhede)

- Cryptographic primitives
  RIJNDAEL (AES), LANE (SHA-3 candidate)
- Secure and compact hardware design
  SPONGENT (lightweight hash), Side-channel attacks

DistriNet (Frank Piessens)

- Low-level vulnerabilities and countermeasures
  Still very relevant in the IoT
- Protected module architectures
  Software isolation with a minimal TCB
- Fully abstract/secure compilation
  Enable security reasoning at high-level languages

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Motivation: Security of IoT Nodes

TI MSP430: designed for low cost and low power consumption

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- Trustworthiness of a node is hard to assess!
  Testing? Formal verification? Observation?
- Protected Module Architectures can help
  (Intel SGX, ARM TrustZone, SMART, TrustLite, Sancus)

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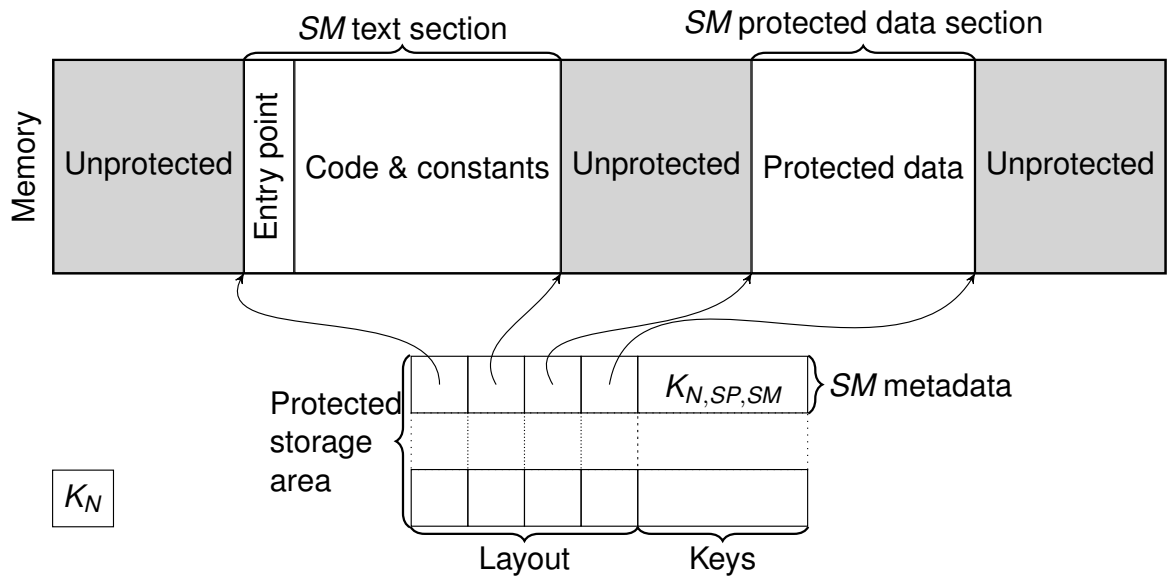
Sancus [NAD+13] enables strong isolation, attestation and communication for embedded software components:

- Implements Program Counter Based Access Control [SPP10] for Software Modules (SMs) on single-address-space architectures



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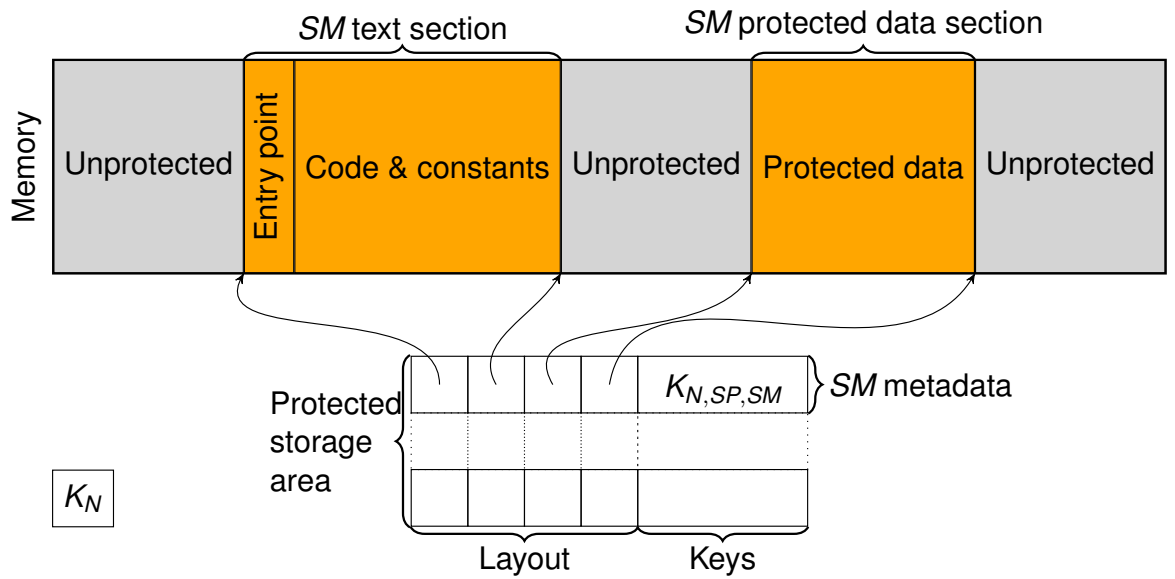
Public and protected sections



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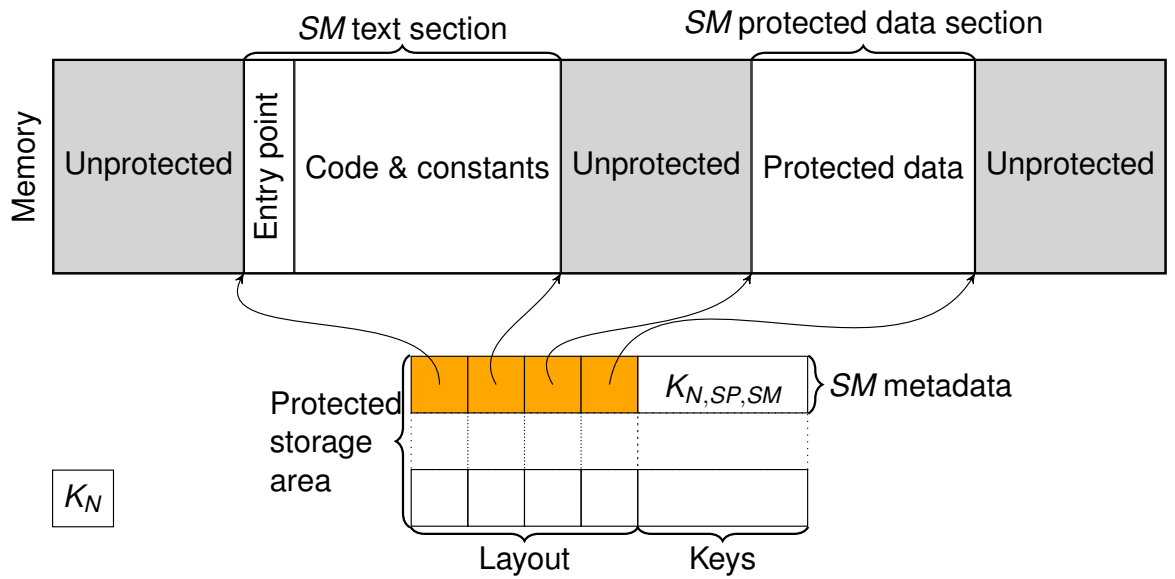
Module layout



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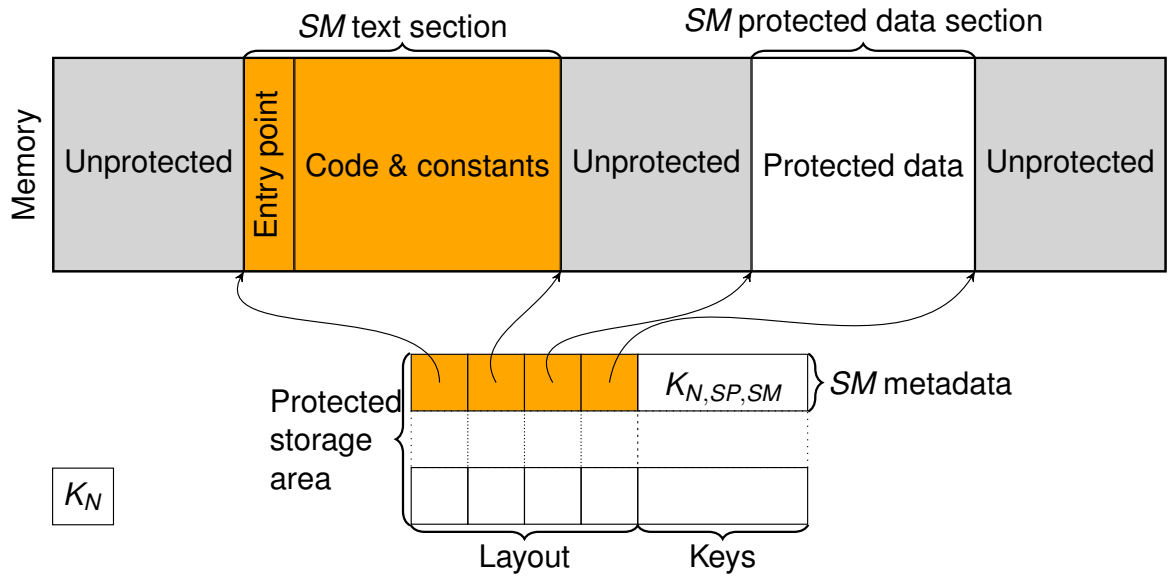
Module identity



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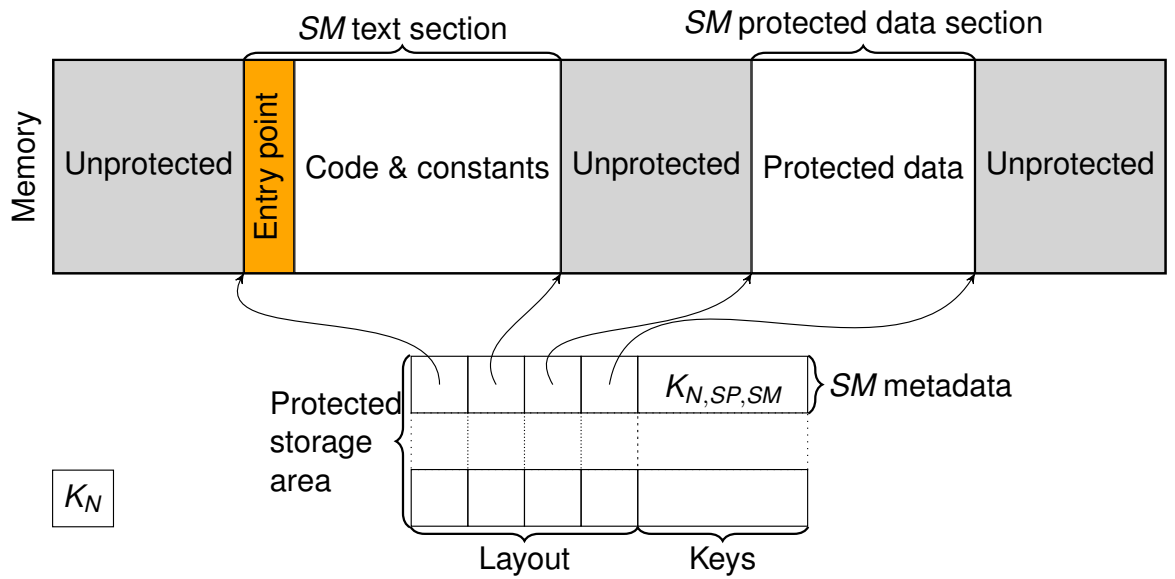
Module entry point



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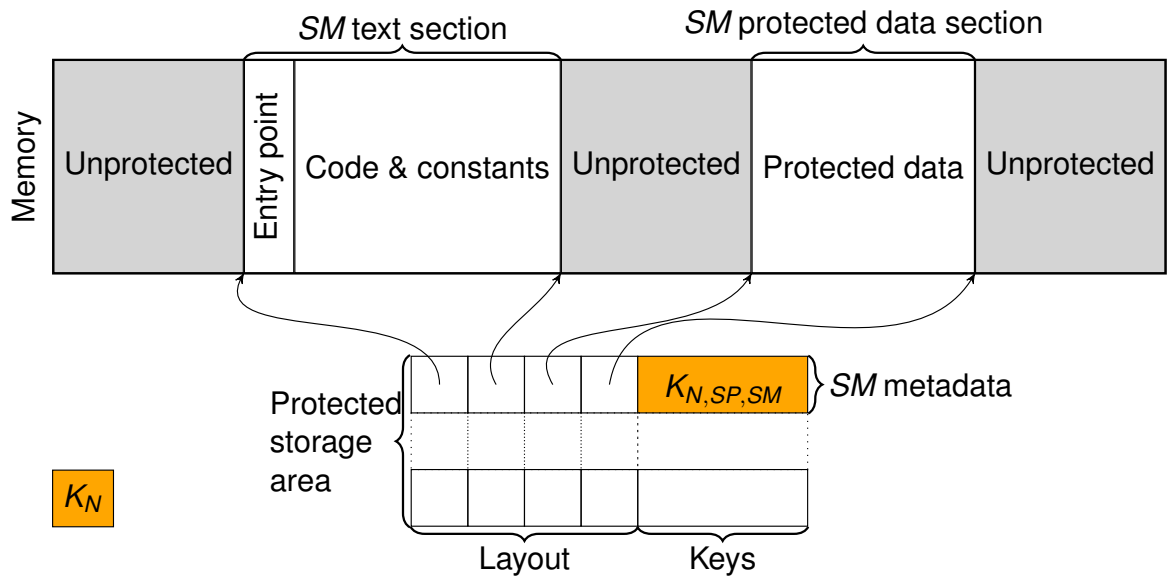
Module keys



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- Isolation vs. shared memory communication [BNMP15]
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Can we use Sancus SMs to implement light-weight and secure inspection components that integrate seamlessly with existing deployment scenarios?

Trust Assessment Modules

Idea

- Securely deploy a protected inspection module to assess the state of an IoT node

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- Modules can be configured to perform inspection tasks autonomously or upon request
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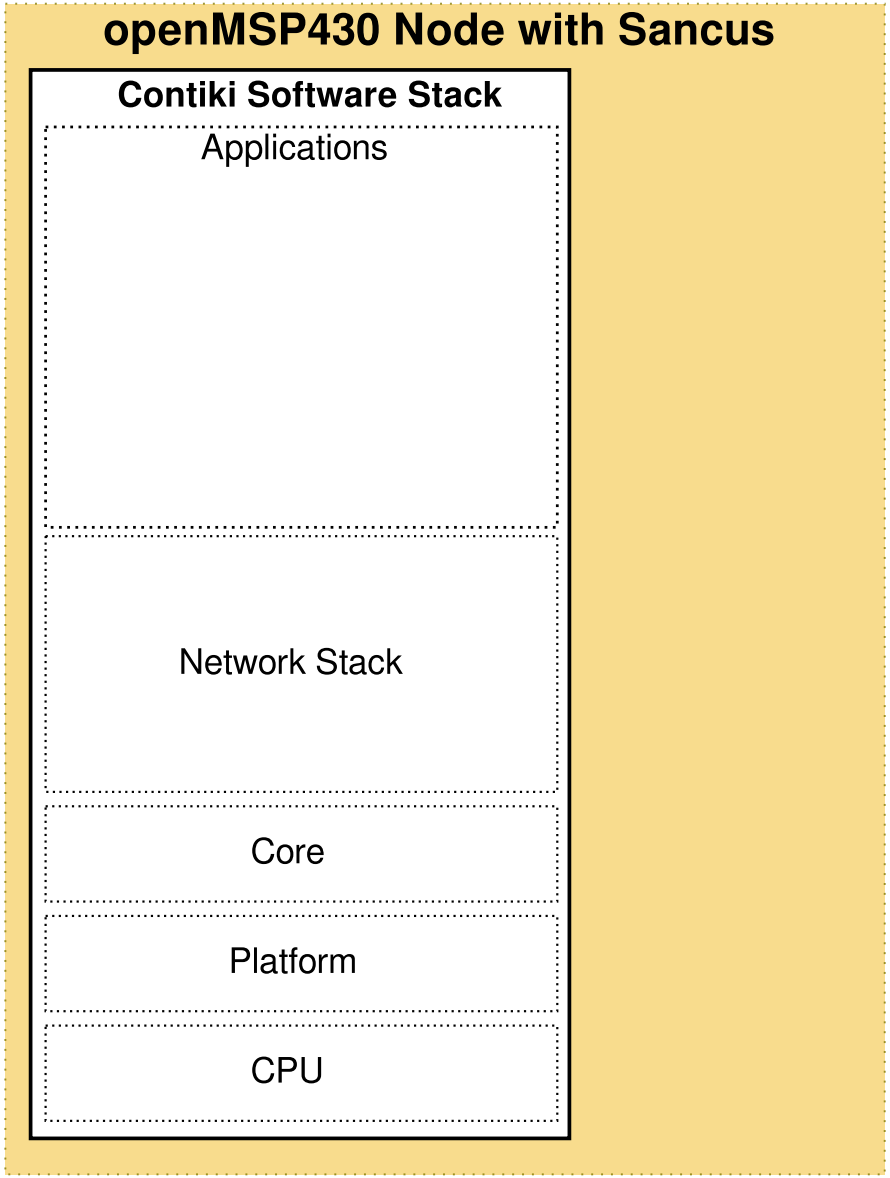
→ Flexible and authenticated node inspection

→ No or minimal changes in existing deployment scenarios

→ Easy reconfiguration impedes attacker adaptation

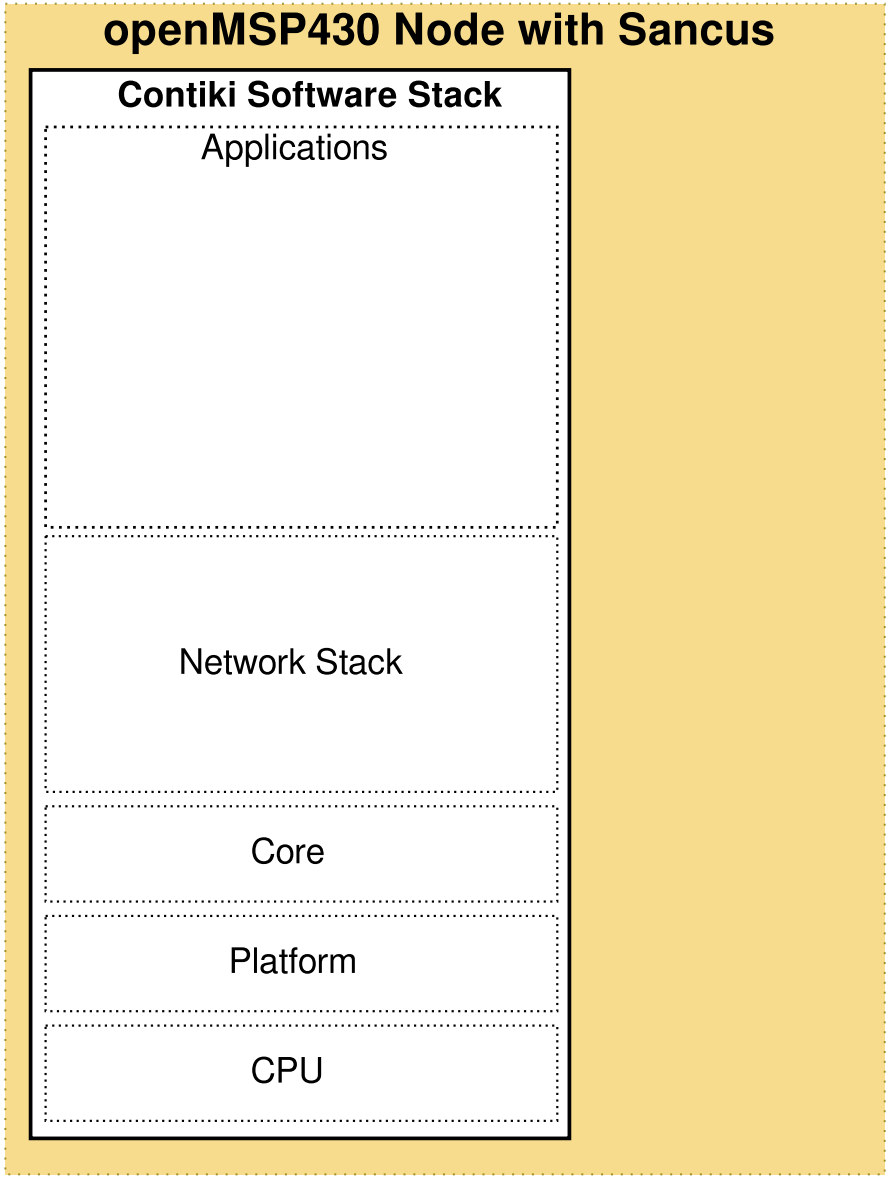
Secure Module Deployment

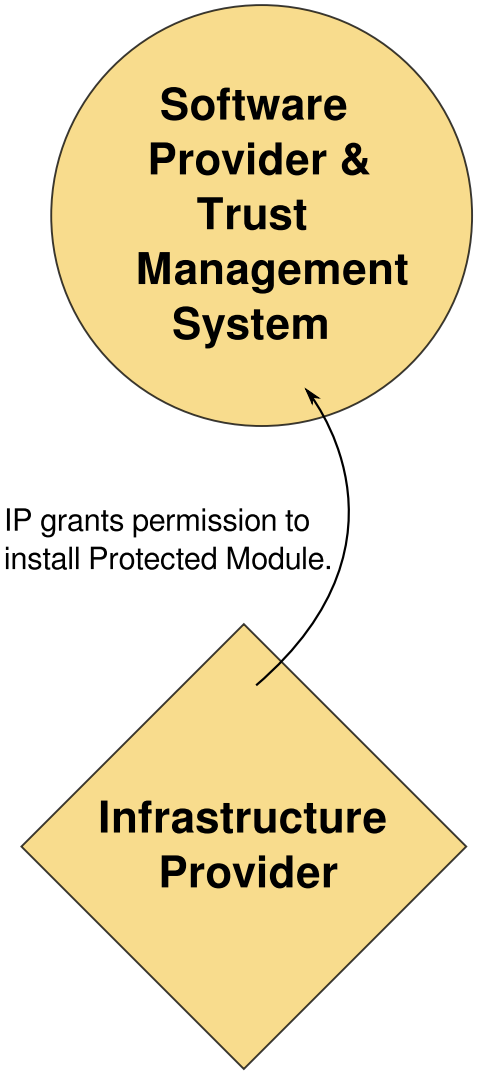


Software Provider & Trust Management System

Infrastructure Provider

Secure Module Deployment





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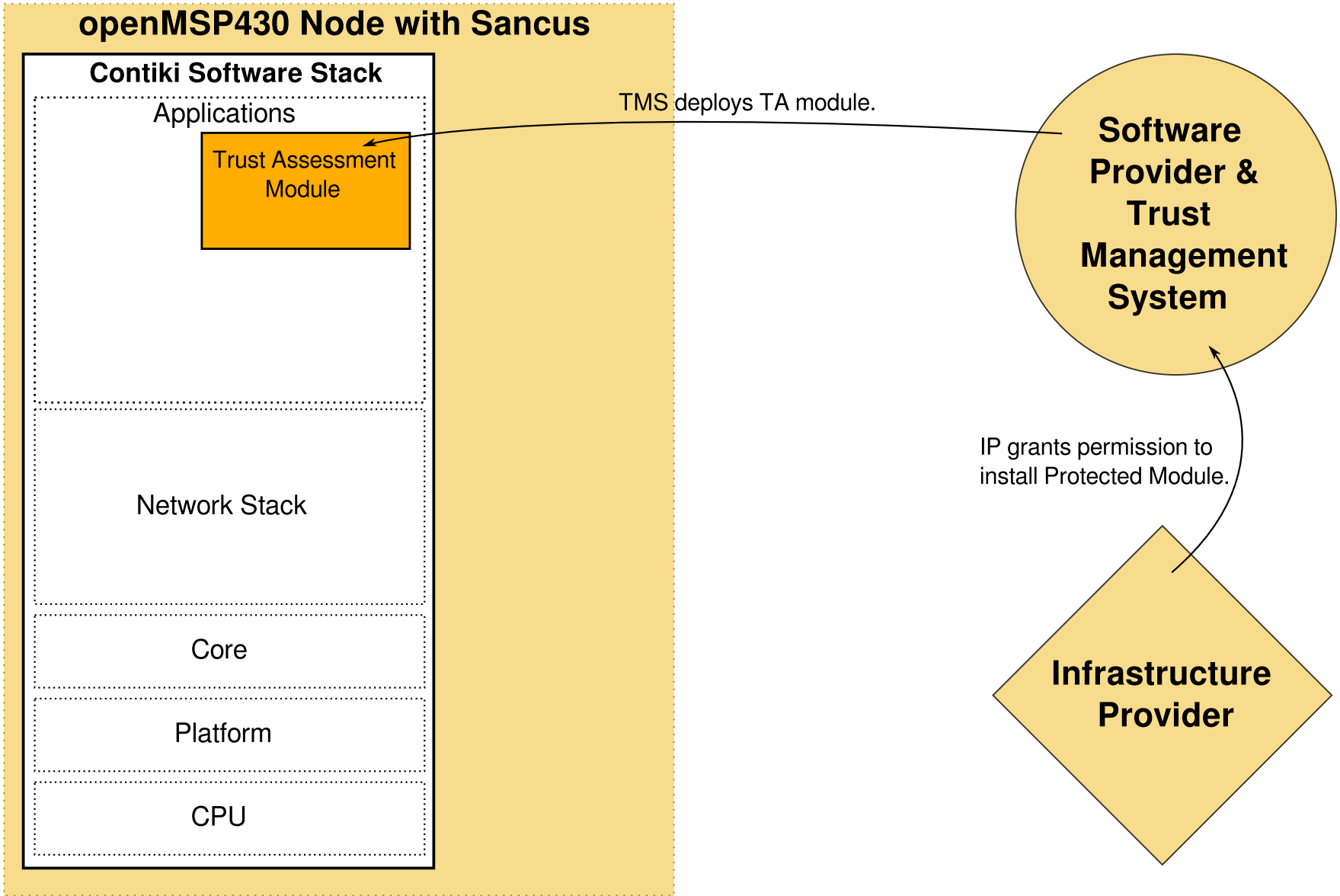

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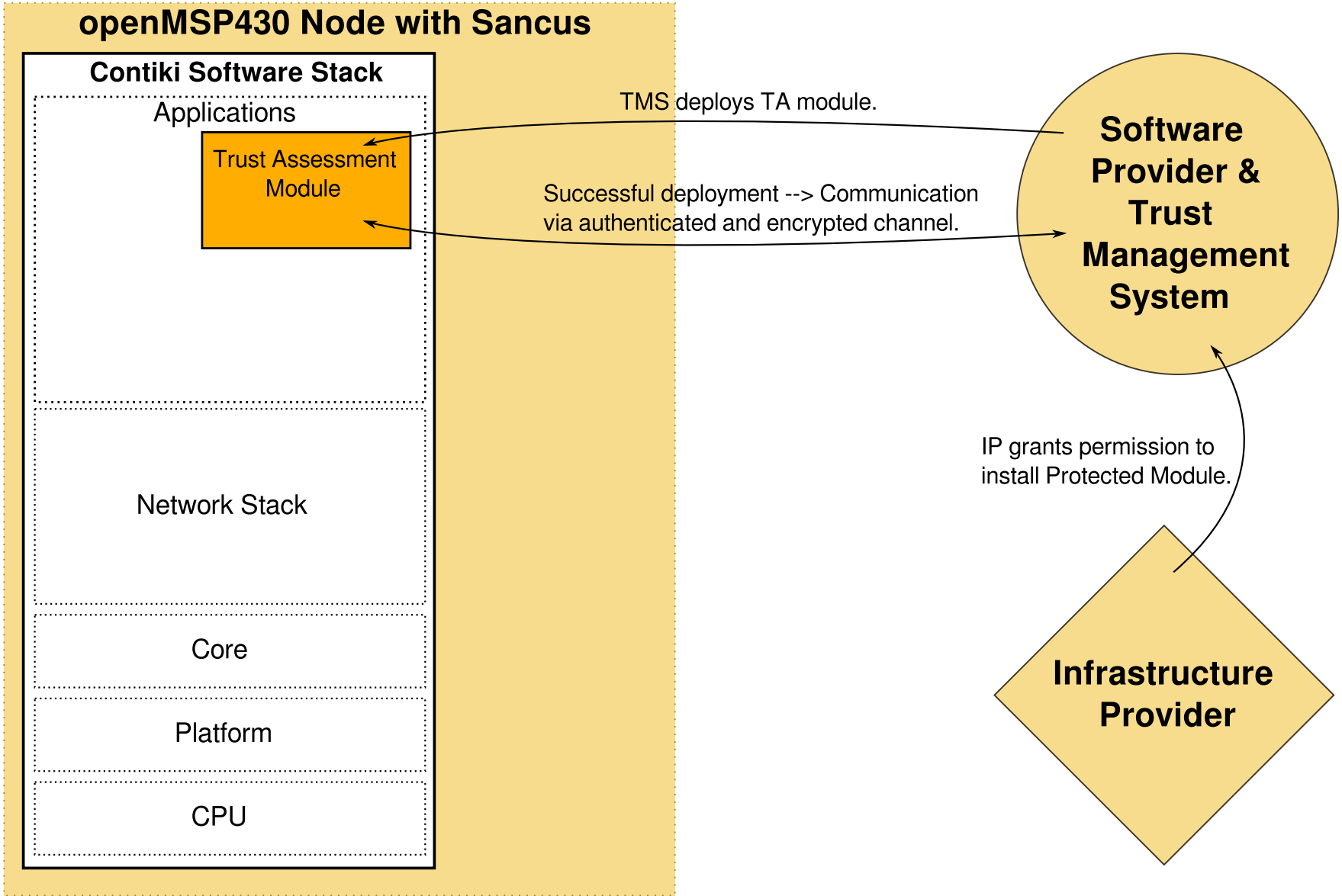
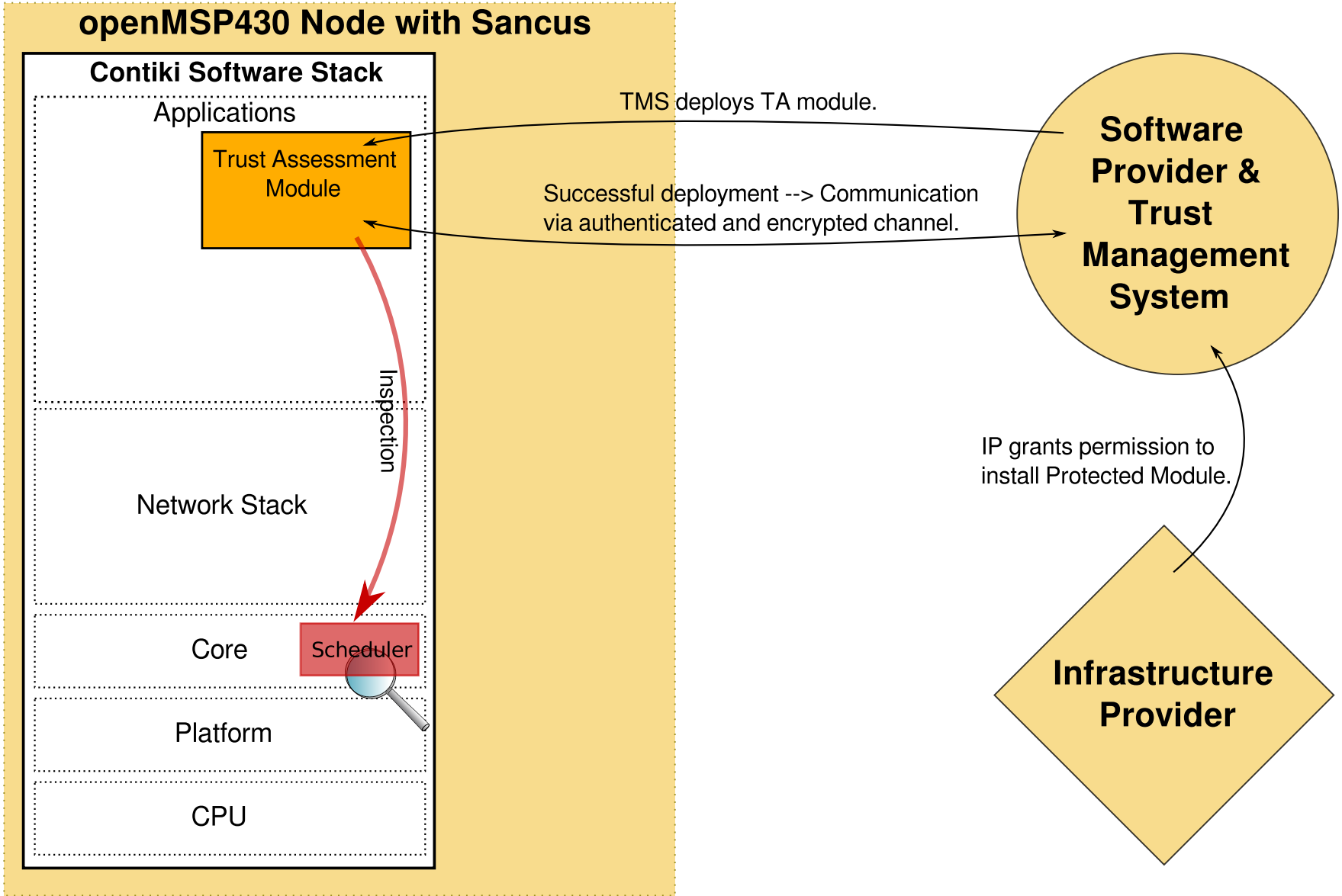


Inspection Targets



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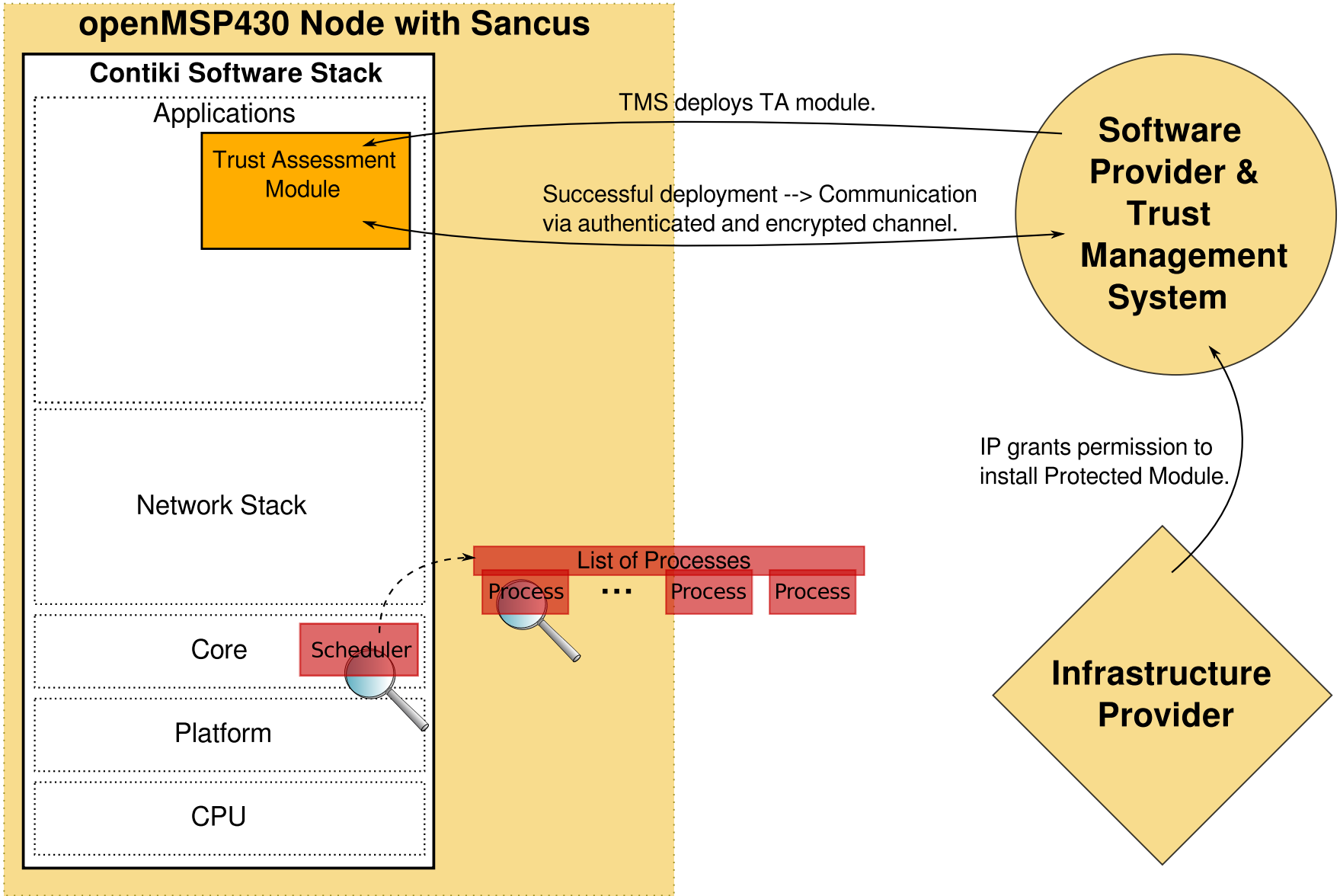

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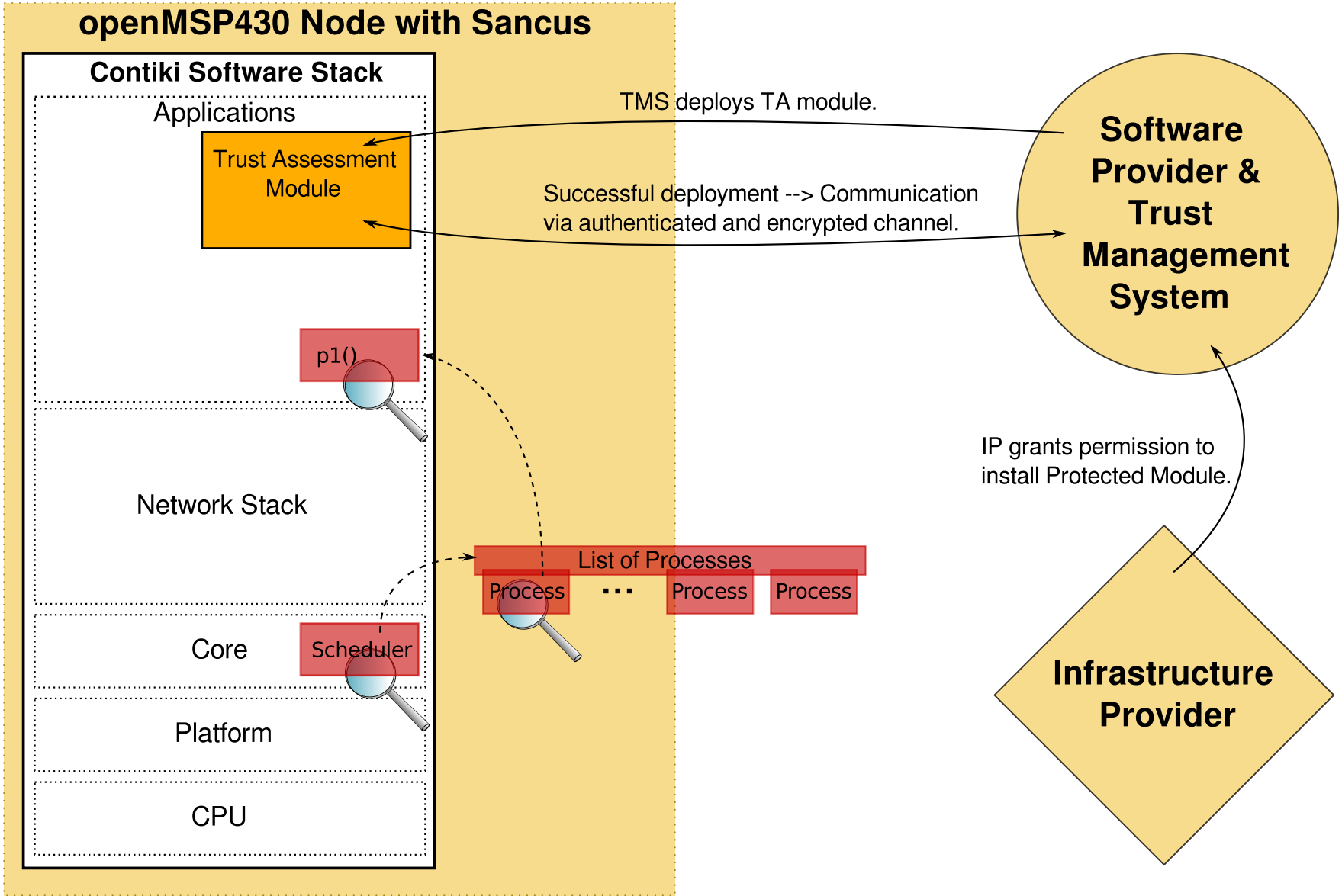

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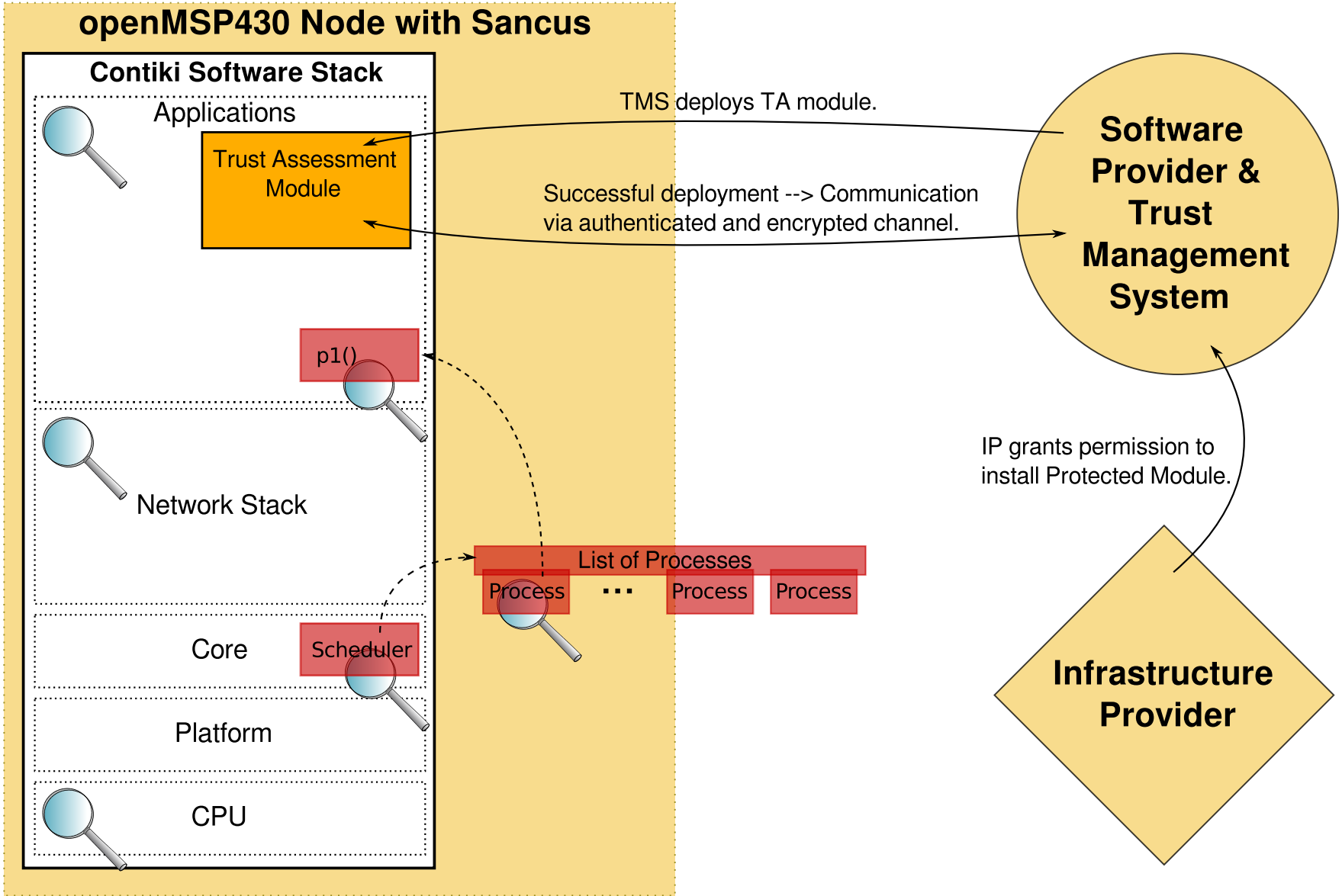

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A Realistic Scenario

Trust Assessment Module monitors and reports

- list of running processes on a Contiki node
- code integrity of the main function of each process
- number of invocations and time of last invocation

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Attacker process periodically

- modifies process list
- modifies code section

Evaluation

Size and execution time of different trust assessment components on an MSP430 running at 20 MHz: 1 cycle corresponds to 50 ns

Function	**Size** in Bytes	**Runtime** in Cycles	**Description**
`TACoreEnable`	58	236,440	Enables module protection and initiates key generation
`TAMainFunc`	430	578 73,678	Main function, initialisation . . . validation run (5 processes, 9 integrity checks)
`TARegisterInvar`	402	1,242 10,762 19,930	Stores meta-data and MACs of 32 B . . . 199 B . . . 399 B
`TACheckInvars`	498	69,659	Checks integrity of 9 address ranges (1833 B)
`TAAddProcess`	568	$\leq$ 18,374	Shadows an entry from the process list and determines length of process function
`TACheckProcesses`	288	2,371	Checks shadowed process data against process list (5 processes)
`TASecureCallProcess`	392	266 $\leq$ 731	Process invocation with no logging . . . logs time and and number of invocations
`TAInvarsStatus`	202	10,254	Encrypts and signs meta-data on integrity-checked code and data (160 B + 16 B nonce)
`TAProcessStatus`	202	17,488	Encrypts and signs meta-data on running processes (320 B + 16 B nonce)
total	3,742	n/a	Code (`.text`) and data (part of `.bss`)

Sancus on Spartan-6: +50 % LUTs and registers, +6 % power consumption

236,440 cycles $\approx$ 0.012 s

Conclusions

Trust Assessment Modules for the IoT

- Based on Sancus, a hardware-only PMA
- Secure and authenticated node inspection
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- Acceptable memory footprint and performance

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Future Work?

Related Work

Alternatives to Sancus

- Server/Desktop: Intel SGX [MAB+13], ARM TrustZone [AF04], TrustVisor [MLQ+10], Fides [SP12]
- Embedded: SMART [EFPT12] & TrustLite [KSSV14]

Related Work

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Trust Assessment on Desktop & Server Systems

- By means of specialised hardware: Copilot [PJFMA04] & Gibraltar [BGI11]
- Kernel extensions & hypervisors: HeapSentry [NPJ13], SecVisor [SLQP07], HyperForce [GNMJ12], etc.

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Trust Management in WSN

- Focuses on observable behaviour of nodes, i.e., communication and plausibility of sensor readings [FGRL07, GMS15, LRAFG10]

Thank you! Questions?

http://distrinet.cs.kuleuven.be/software/sancus/

Further reading: “Lightweight and Flexible Trust Assessment Modules for the Internet of Things.” Mühlberg et al., ESORICS 2015, LNCS vol. 9326, pages 503–520, Springer.

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Secure Module Deployment