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A Practical Guide for CIP Security Device Developers

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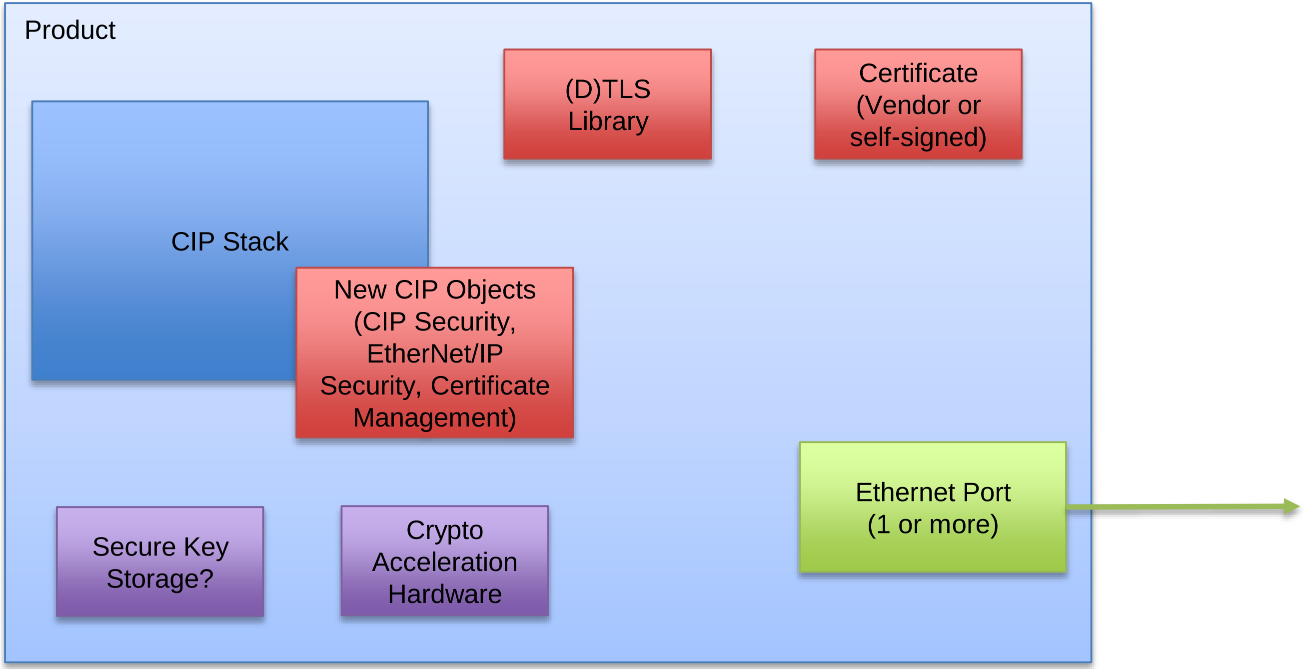
What is “A Practical Guide to CIP Security For Developers”?

- We want to give developers some hints and tips on what to do when implementing this functionality
- Although there is a lot of information in the spec, there is also some use in “non-normative” information
- None of the recommendations would be necessary for compliance
  - In some places perhaps no recommendation is made, just important considerations are noted

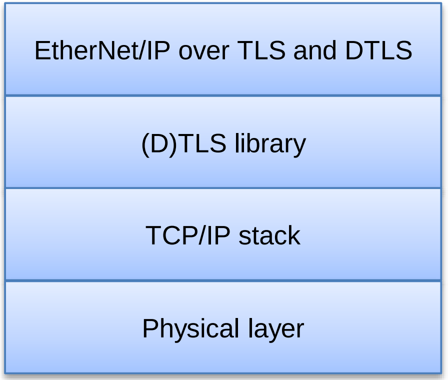
Before CIP Security

After CIP Security



Topic: Library Selection

- The core component in CIP Security over EtherNet/IP
  - Transport Layer Security (TLS)
  - Datagram Transport Layer Security (DTLS)
- A large and complex piece of software
- It’s probably a lot better to get a (D)TLS library than to try and write this code yourself ☺



Topic: Library Selection

- Many different vendors and projects
  - OpenSSL
  - wolfSSL
  - mbed TLS (formerly PolarSSL)
  - MatrixSSL
- At least a few vendors are using WolfSSL, that is a commercial library that is working for these purposes
  - Others?

Topic: Library Considerations

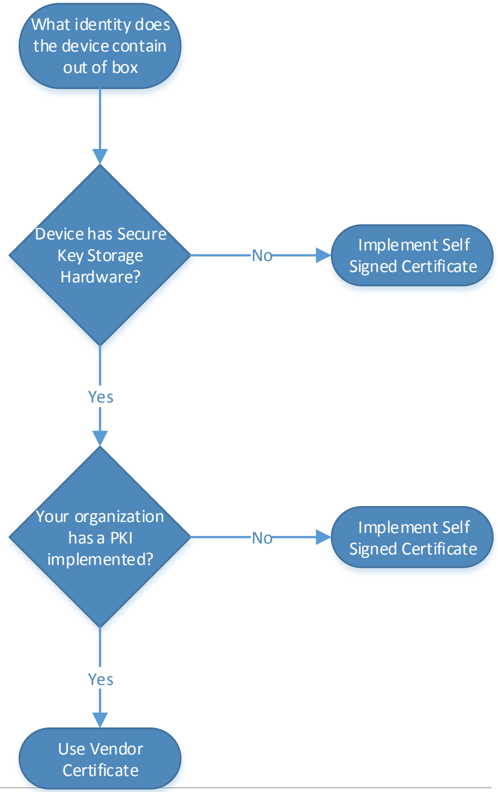
- Cost/Licensing
  - What is the budget for a (D)TLS library?
  - Is it open source?
  - Royalty based or licensed outright?
- Support
  - What happens when there are questions/work requests?
  - What level of documentation is available?
  - How intuitive is the API?
- Reputation
  - Is the library/vendor respected in industry?
  - Do the library developers have security expertise?
- Vulnerability Management
  - How are updates produced and consumed?
  - Are people actively testing the library for security issues?

Topic: Library Considerations

- Footprint
  - Memory constraints, what size is acceptable (both RAM and non-volatile)?
  - How configurable is the library; can unneeded features be compiled out of the binary?
- Capabilities
  - Does it support everything that is needed for CIP Security (e.g. NULL Ciphersuites)?
- Performance
  - Can it be optimized?
  - Does it integrate with hardware?
- Technology
  - Does it work well in the given environment (e.g. a Java library won’t work in a C environment)?
  - Is the API standard and fits in with the product’s architecture?

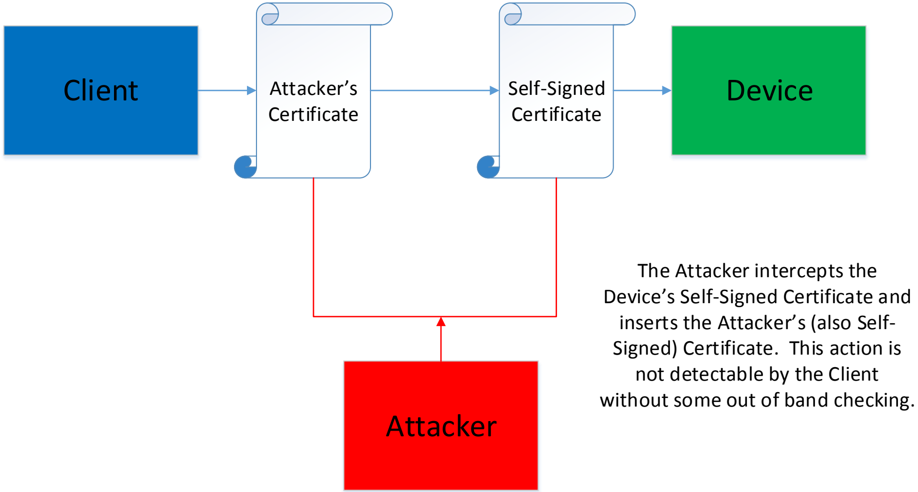
Topic: Key Management and Secure Identity

- Vendor Certificate vs. Self-Signed Certificate
  - If a Vendor Certificate is used, private key must be stored securely
  - Both work equally well for CIP Security
  - Vendor Certificate has may be useful for other things (securely identify a given vendors products, bootstrapping other things, etc…)
  - Essentially, low cost option vs. a more expensive yet more flexible/extensible option



Vendor Certificate CIP Security Benefit

- Vendor Certificate can be used to protect against “Man In The Middle” attacks on initial provisioning
  - However, only if the Vendor’s root was built in to the product
  - And only if both sides have a Vendor Certificate (unlikely for a software tool to have this)



Topic: Key Management with Vendor Certificate

- Need a secure place to store the key
  - There are solutions for this; TPMs, Secure Key Store chips, some FPGAs have built-in capabilities, etc…
- Need a mechanism to sign the Vendor Certificate
  - PKI; this comes with all the issues that are normally associated with the PKI
    - Managing a Certificate Authority – protect the keys!
    - Managing a Registration Authority – how to validate identity of requestors
    - How to access the PKI (e.g. just over a network or other mechanisms?)

```
X509 Certificate:
Version: 3
Serial Number: 6e6e5112000000000f24
Signature Algorithm:
    Algorithm ObjectId: 1.2.840.10045.4.3.4 sha512ECDSA
    Algorithm Parameters: NULL
Issuer:
    CN=Rockwell Automation - Manufacturing Intermediary CA 5
    O=Rockwell Automation, Inc.
    C=US

 NotBefore: 12/16/2015 12:19 PM
 NotAfter: 12/6/2055 12:19 PM

Subject:
    CN=1756-L85E (00b48f94)
    O=Rockwell Automation, Inc.
    C=US

Public Key Algorithm:
    Algorithm ObjectId: 1.2.840.10045.2.1 ECC
    Algorithm Parameters:
    06 08 2a 86 48 ce 3d 03  01 07
        1.2.840.10045.3.1.7 ECDSA_P256 (ECDH_P256)
```

Topic: Connection Origination

- Lots of devices are just “targets”, don’t originate connections
- Connection origination has additional considerations
  - How would a device know to originate connections as secure?
    - In an environment that has a mix of CIP Security capable devices and non-CIP Security capable devices this can be challenging
    - Otherwise non-secure ports can be disabled and all communications can be over CIP Security sessions

Topic: Debugging

- Previously packets can be sniffed using Wireshark or a similar tool
- If confidentiality is enabled this becomes much harder
  - Suggestion is just to debug it using a NULL ciphersuite
  - Wireshark plugins for confidentiality are available, but session keys are needed (use Wireshark 2.1.0 https://2.na.dl.wireshark.org/win64/Wireshark-win64-2.1.0.exe)
  - Considerations of how to allow for this
    - Don’t want this enabled in the field!!!
    - But, developers would want to be able to use this relatively easily

Topic: Testing Tools

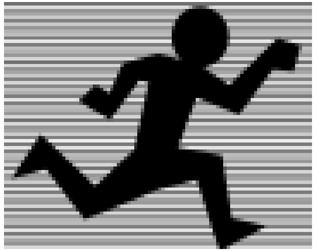
- OpenSSL
  - Useful for initial testing during early development
    - Together with Wireshark the initial TLS handshake can be debugged and tested
  - Perform the initial shake and key-exchange
    - Handy when performing performance evaluation and optimizations
  - Test and verify supported TLS versions
- Nmap
  - List all supported cipher suites

Topic: Testing Tools

- May want a tool that runs on a PC and originates connections
  - Send configuration to the device
  - Initiate connections to the device
  - Easily debug communications via a “transparent client” (simple to allow this tool to show what communications it sends or receives)

Topic: Performance Configurations

- There is (of course!) a cost to enabling CIP Security
- Can a given product handle the performance degradation?
  - Connection startup
    - Computational cost to handshaking (especially certificate verification)
    - Extra steps/data over the network for handshaking
  - Data flow during connection lifetime
    - Latency concerns; can performance targets be achieved?



Topic: Hardware Architecture

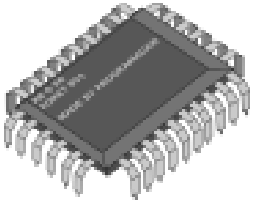
- Including specialized hardware on a CIP Security product can be very helpful (although not strictly necessary)
- Three general types of hardware:
  - Cryptographic Accelerator
  - Secure Key Storage
  - Entropy Generator

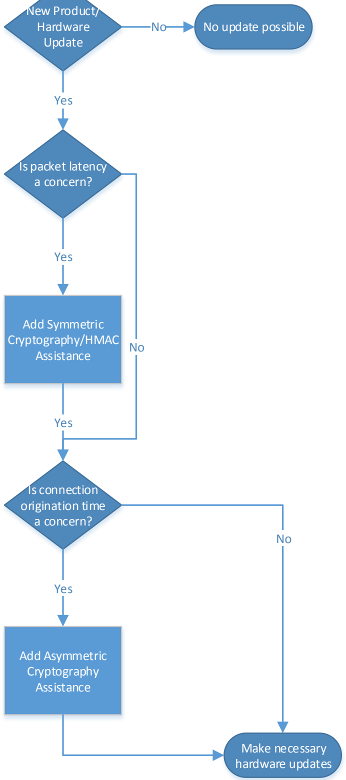
Hardware Considerations

- Regardless of what hardware is included, there are some common considerations
  - Trust Boundaries: is the hardware in an ASIC, on a PCB, on a USB stick, etc…
  - Performance: does the hardware achieve target performance
  - Capabilities: algorithms supported, interfaces, etc…
  - Cost: can the cost of adding the extra hardware be justified?
  - Contention: do multiple parts of the system need to access the hardware at the same time? If so, what mechanism can be used to arbitrate this

Topic: Cryptographic Accelerator Hardware

- Hardware can be used to make increase performance of cryptographic operations
  - Anywhere from a modest assist to near/at line speed
  - Of course this requires investment; whether or not it is worthwhile depends on many factors
  - However, given the importance of CIP Security, it is probably a good thing to at least consider for any new products





Topic: Other Hardware

- Secure Key Storage Hardware
  - As mentioned previously, this is needed for a Vendor Certificate
  - Other keys can be stored here (like key provisioned as part of the user granted identity)
  - It is important to consider key lengths and algorithms supported

- Entropy Generating Hardware
  - Including a True Random Number Generator is very helpful for secure generation of keys
  - Generation of cryptographic entropy is very difficult without specialized hardware

Topic: Entropy

- A good library will have at least one PRNG algorithm for generating random data
- However, those algorithms need to be seeded with truly random data
- This has to come from something physical
  - Cryptographic hardware often includes a TRNG
  - If you don't have a TRNG then you need to get creative
    - Look for things in the system that are non-deterministic
    - There's been work done on this, several papers published
    - Guidance could be provided for a few standard mechanisms

Topic: Cipher suites

- There are a lot of ciphersuites available, what should be used
  - CIP Security Spec defines some required ones
  - There are many others
- Asymmetric – generally 2 choices
  - Elliptic Curve offers same or better security at a smaller key size
  - RSA is more widely deployed

NIST SP 800-57 Pt. 1 Rev. 4

Recommendation for Key Management: General

Table 2: Comparable strengths

Security Strength	Symmetric key algorithms	FFC (e.g., DSA, D-H)	IFC (e.g., RSA)	ECC (e.g., ECDSA)
≤ 80	2TDEA[21]	$L = 1024$ $N = 160$	$k = 1024$	$f = 160\text{-}223$
112	3TDEA	$L = 2048$ $N = 224$	$k = 2048$	$f = 224\text{-}255$
128	AES-128	$L = 3072$ $N = 256$	$k = 3072$	$f = 256\text{-}383$
192	AES-192	$L = 7680$ $N = 384$	$k = 7680$	$f = 384\text{-}511$
256	AES-256	$L = 15360$ $N = 512$	$k = 15360$	$f = 512+$

Topic: Cipher suites

- Confidentiality, AES is essentially the gold standard
  - There are a lot of variations to this though
  - Generally the ones defined in the CIP Security Specification should be reasonable
  - Most TLS libraries will support many others; if space is not an issue other options can be given
    - CCM and GCM are both authenticated algorithms, give some additional benefit at the cost of complexity
- HMAC
  - SHA-2 is widely deployed and supported, SHA-1 still accepted by NIST for HMAC
  - SHA-3 recently released, yet to be widely adopted

Topic: System time

- X.509 v3 certificates have a field defining its validity period
  - notBefore and notAfter
- Likely the EtherNet/IP device doesn't have an RTC
  - Thus the validity period of the certificate can't be verified
- The EtherNet/IP device could implement NTP or IEEE-1588
  - Though none of them are secure
- Roughtime might be an alternative in the future

THANK YOU