Is Security on Your Nerves?

Paul Rogers

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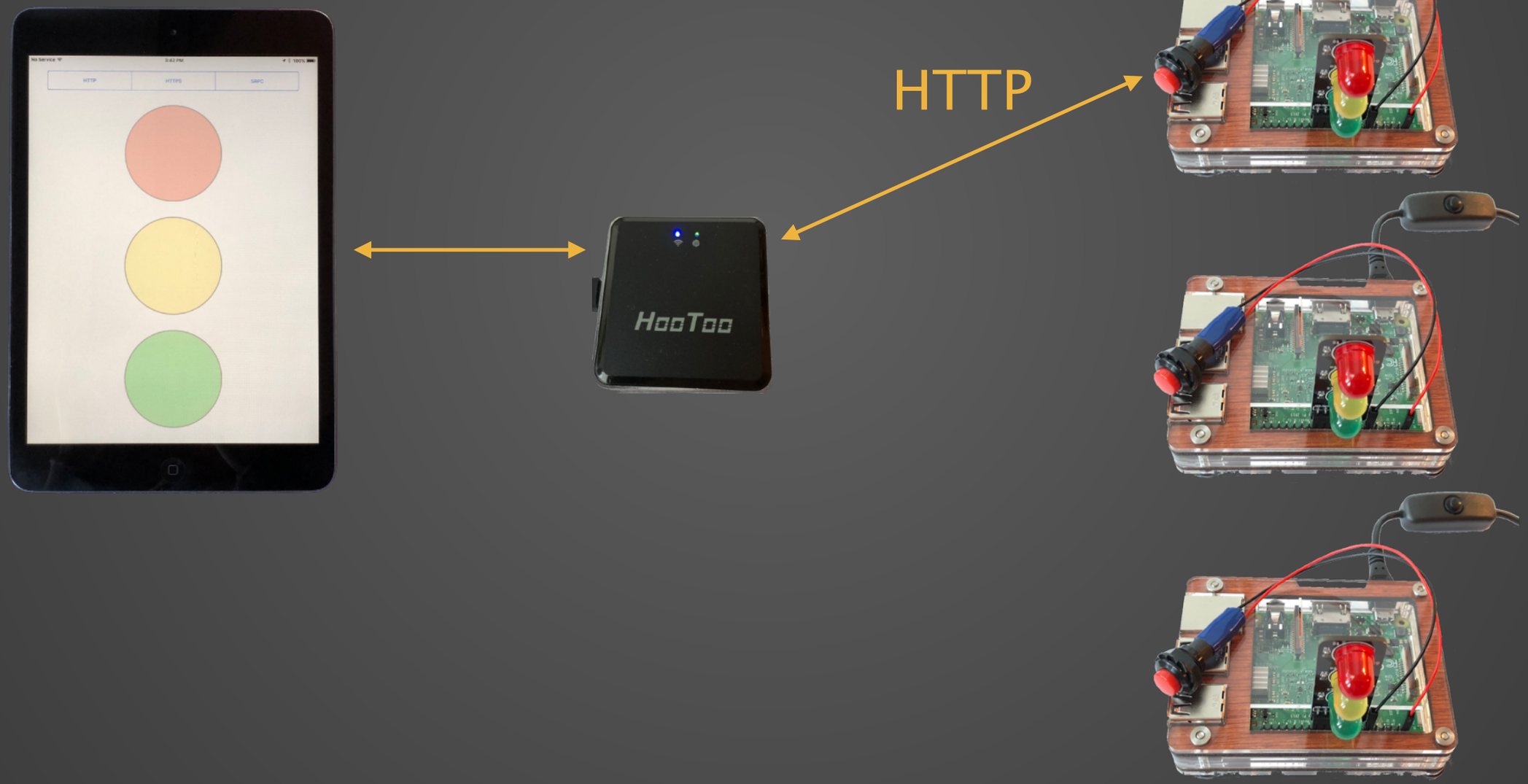
Scenario

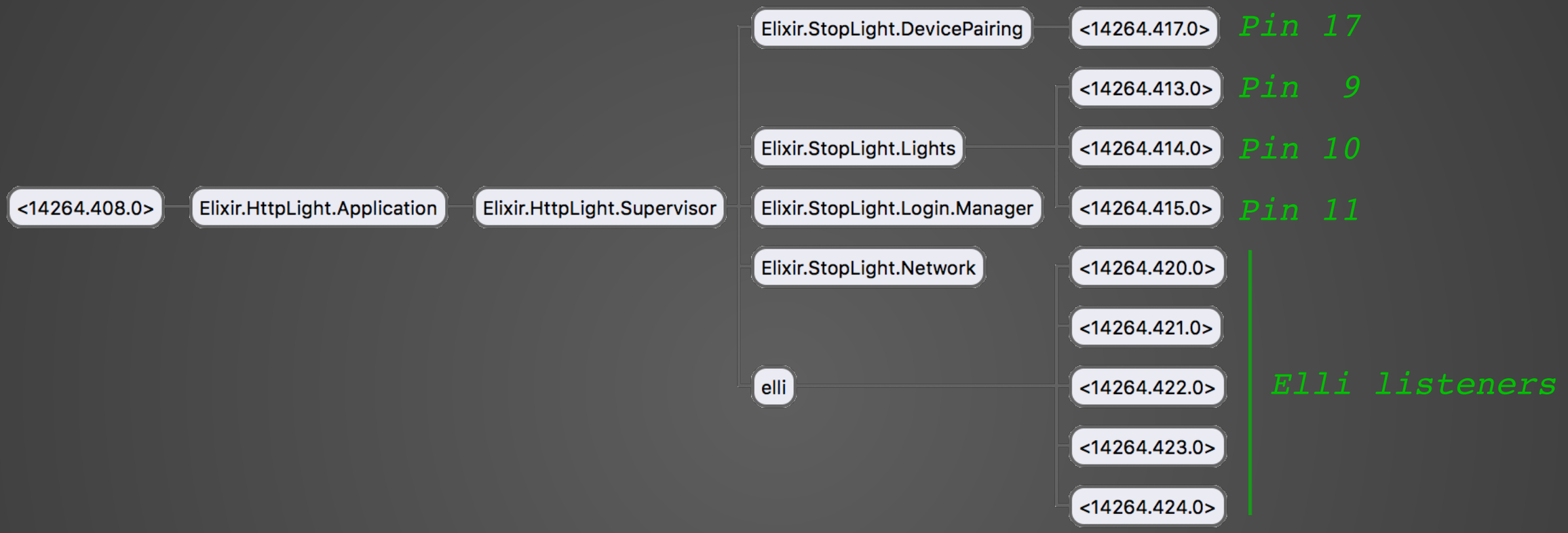
iPad controls stop light on an RPi3 device



System Overview

- RPi3 Elixir Nerves
  - ElixirALE - Stoplight and momentary switch
  - Elli - HTTP interface
- iPad
  - iOS app responding to tap gestures
- Interaction
  - RPi3 is placed in “pairing” mode
  - iPad pairs with RPi3
  - iPad logs into the RPi3
  - iPad controls RPi3 stoplight via JSON API

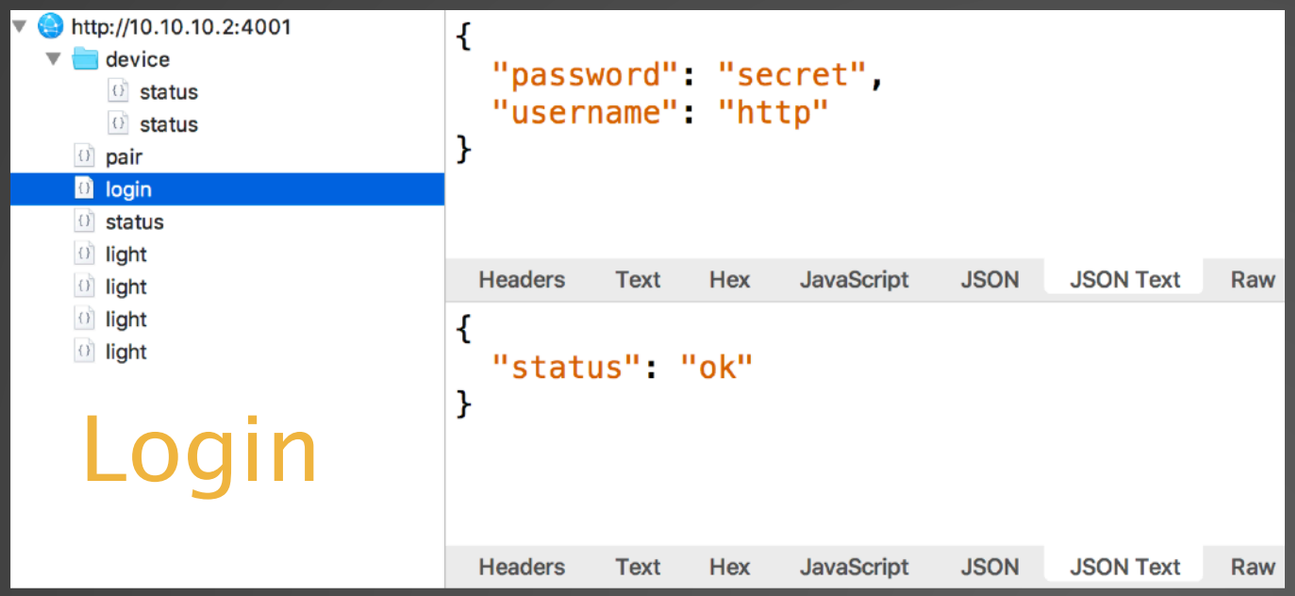
RPi3 Application Structure




```
config :stop_light, :elli,
  port: 4001,
  stack: [
    {StopLight.Elli.StatusHandler, []},
    {HttpLight.Elli.LoginHandler, []},
    {StopLight.Elli.LightsHandler, []}
  ]
```

```
config :stop_light, :elli,
  port: 4003,
  stack: [
    {SrpcElli.ElliHandler, []},
    {StopLight.Elli.StatusHandler, []},
    {HttpLight.Elli.LoginHandler, []},
    {StopLight.Elli.LightsHandler, []}
  ]
```

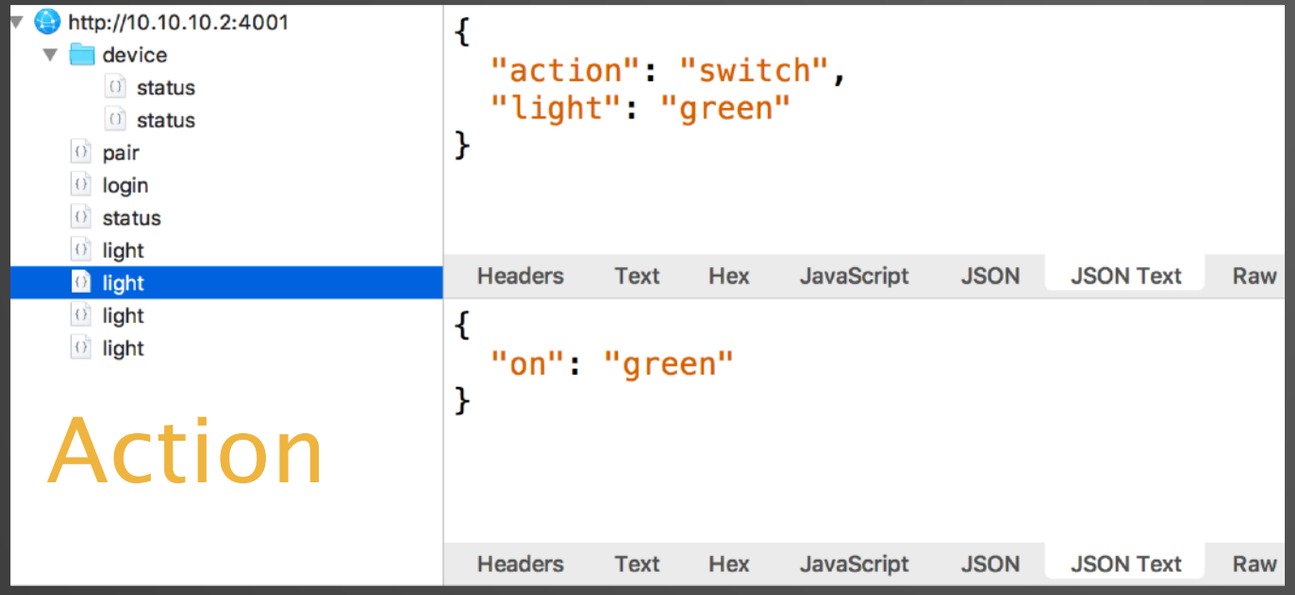
HTTP



Login

Request

Response



Action

Request

Response

```
curl -d '{"action":"switch","light":"red"}' 'http://10.10.10.2:4001/light'
```

curl

HTTP Issues

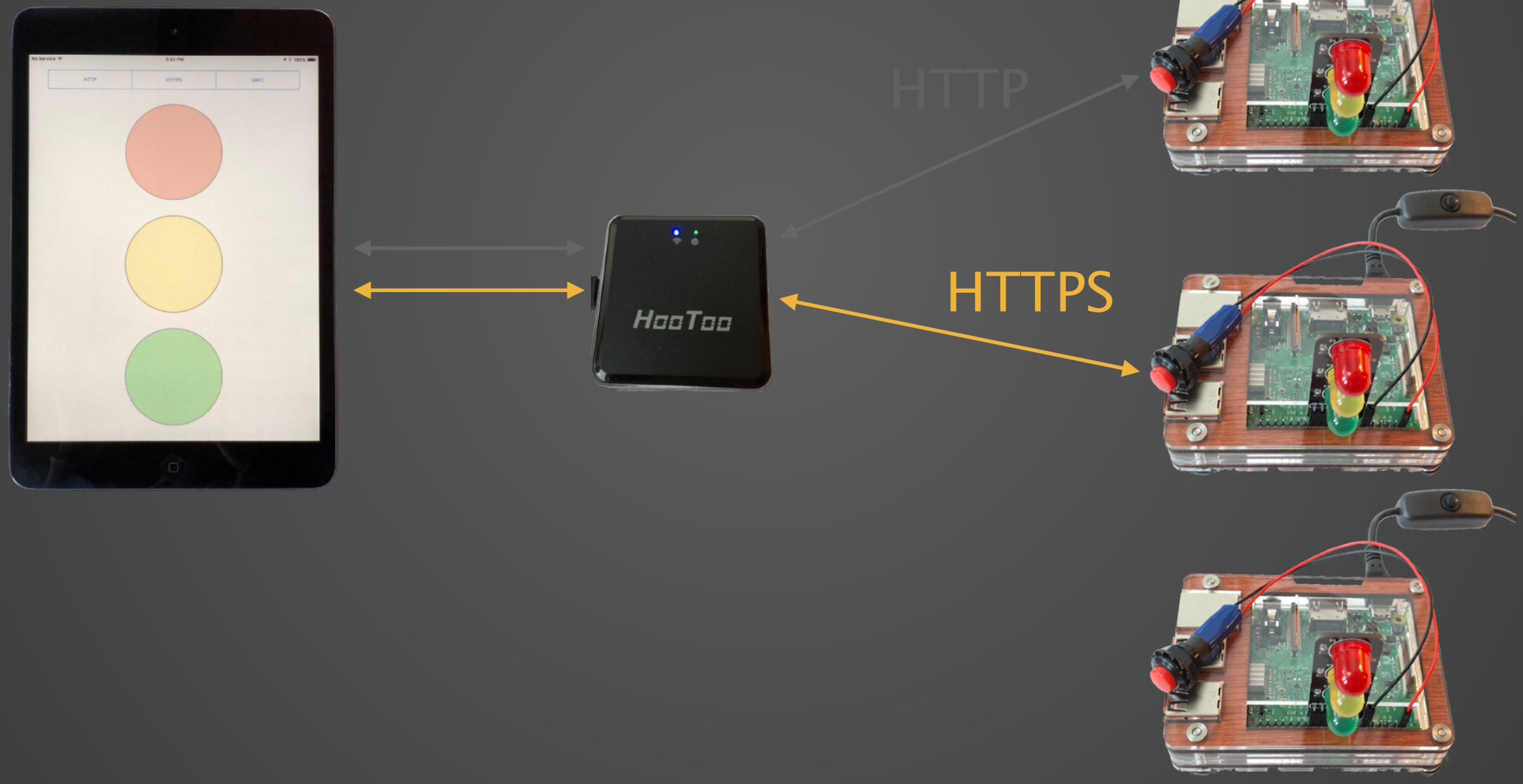
- Eve can snoop communications
  - Plaintext userid & password
  - Capture application data
- Mallory can snoop communications
  - Alter traffic
  - Manipulate API for fun and profit
- Mallory can *control* the stoplight *independently* of the iPad

Add Security

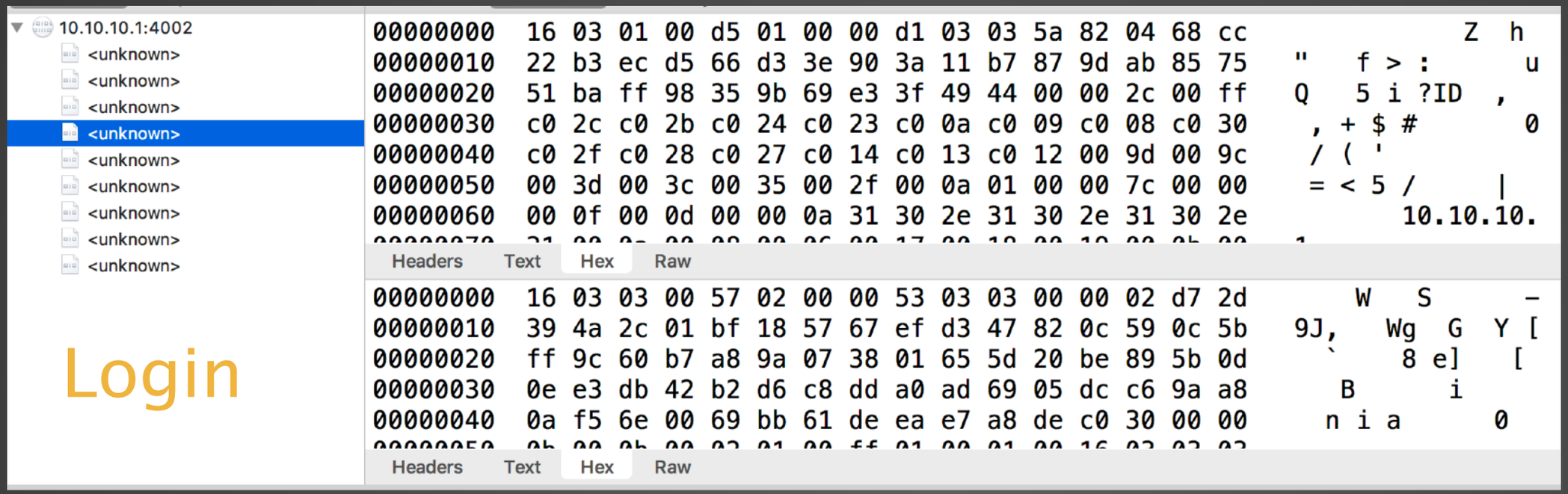
- Encrypt Communications
  - Use symmetric key encryption
    - How do we get the key on the iPad and RPi3?
- Pre-Shared Key
  - Significant issues (forward secrecy, key refresh & maintenance)
- Dynamic Key Establishment
  - Asymmetric scheme to establish a symmetric key
  - Symmetric encryption to provide secrecy

Scenario

iPad controls stop light on an RPi3 device



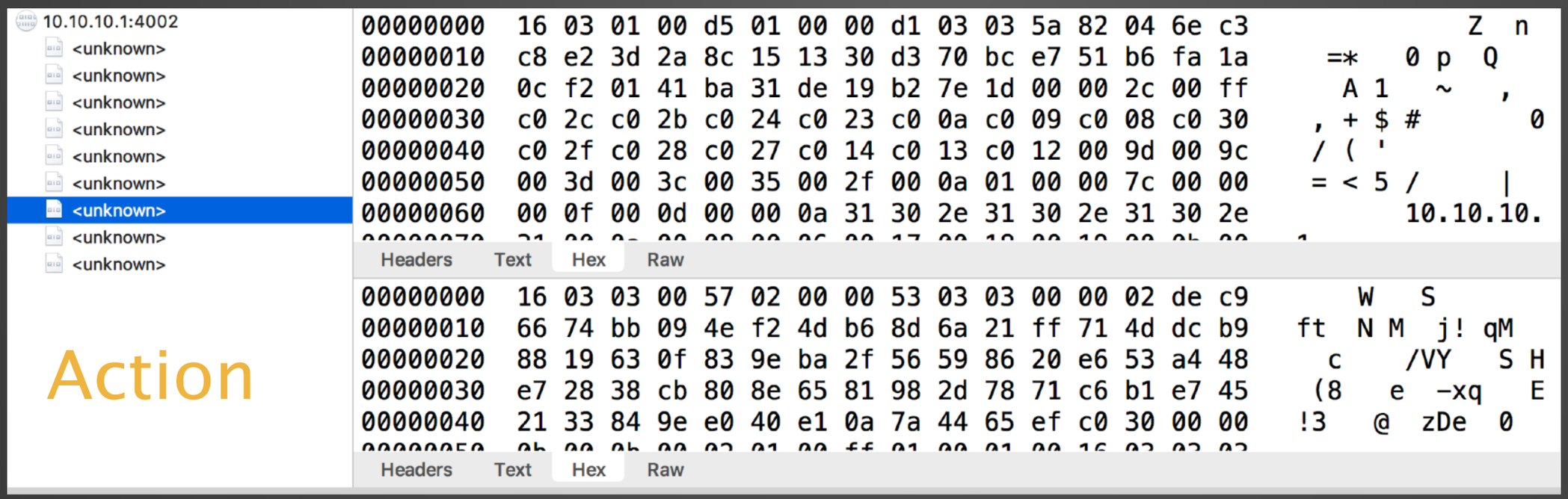
HTTPS



Login

Request

Response

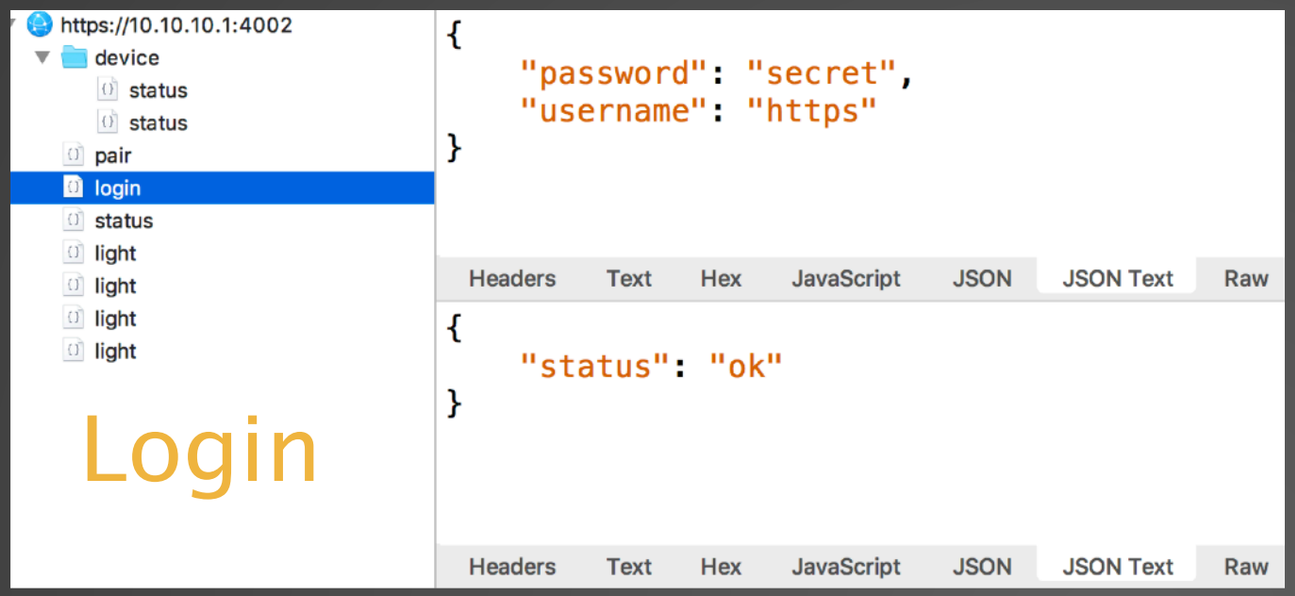


Action

Request

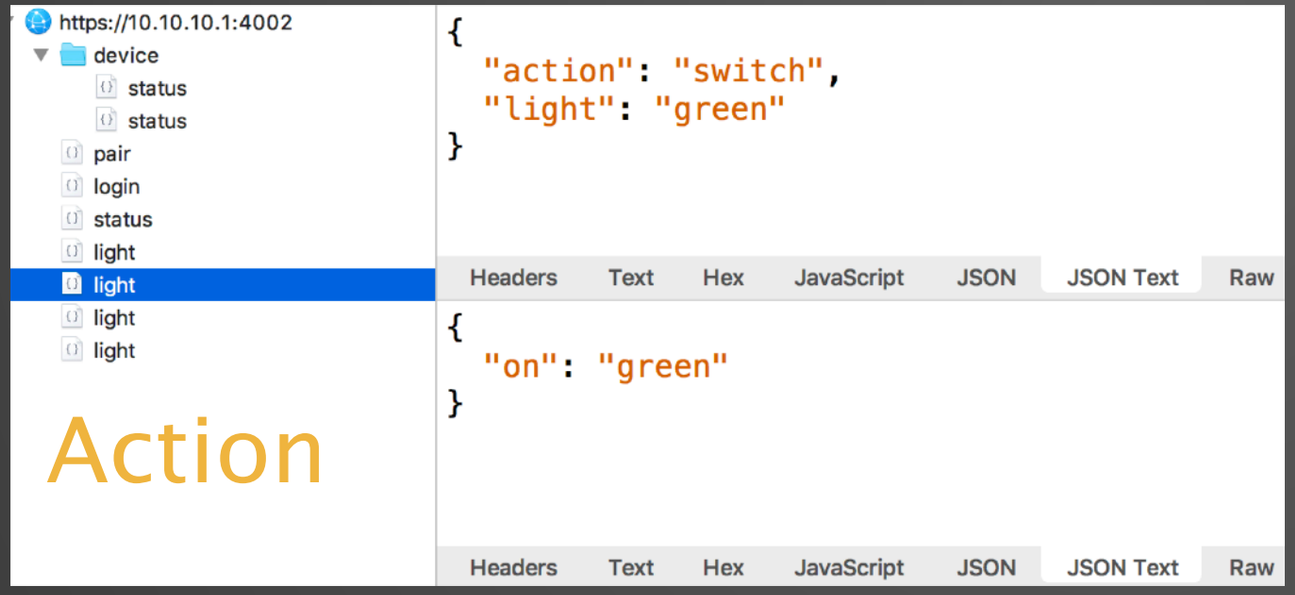
Response

HTTPS with MitM



Request

Response



Request

Response

```
curl -k -d '{"action":"switch","light":"red"}' 'https://10.10.10.1:4001/light'
```

curl

HTTPS Issues

- Mallory can snoop* iPad traffic through legitimate use
  - Manipulate API for fun and profit
- Mallory can *control* the stoplight independently of the iPad
- MitM can snoop communications
  - Plaintext userid & password
  - Capture application data
  - Alter traffic

* Even if the iPad app uses public key pinning

Diffie–Hellman

Chuck and Sara agree to use $g = 2,\ N = 13$ (public)

Chuck			Sara
Random	$a = 5$		$b = 8$ Random
Computes	$A = g^a \,\%\, N$		$B = g^b \,\%\, N$ Computes
	$A = 2^5 \,\%\, 13$		$B = 2^8 \,\%\, 13$
	$A = 6$		$B = 9$
		6 →	
		← 9	
	$\mathrm{K} = B^a \,\%\, N$		$\mathrm{K} = A^b \,\%\, N$
	$\mathrm{K} = 9^5 \,\%\, 13$		$\mathrm{K} = 6^8 \,\%\, 13$
	$\mathrm{K} = 3$		$\mathrm{K} = 3$

- Chuck and Sara *establish* $\mathrm{K} = 3$ via *key agreement*
- If Eve knows g, N and captures 6,9 it is difficult* to calculate K
- Anonymous key agreement
  - Susceptible to Man-in-the-Middle (MitM) attack

* The DH problem is linked to the discrete logarithm problem

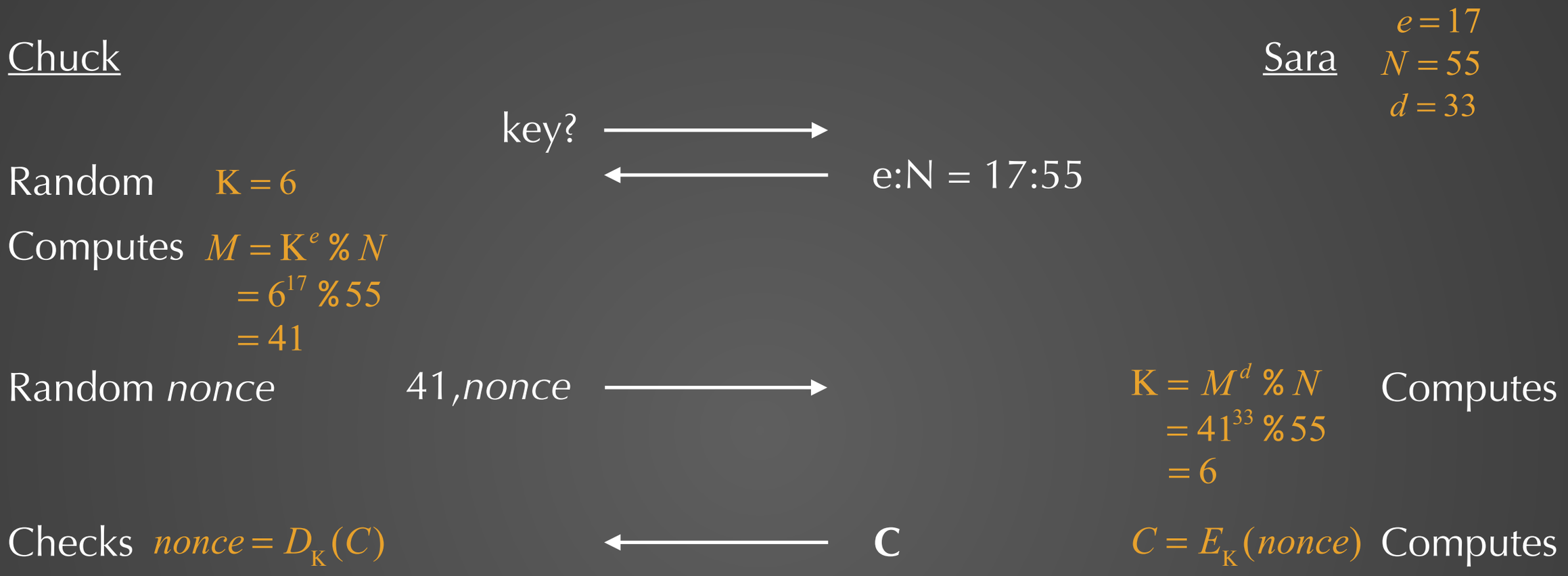
RSA (simplified)

- Sara creates a key pair
  - Chooses $p = 5, q = 11 \Rightarrow N = pq = 55$ & $\varphi(N) = (p-1)(q-1) = 40$
  - Chooses $e = 17$, finds d where $(e \cdot d)\ \%\ \varphi(N) = 1$

$$\Rightarrow (17d)\ \%\ 40 = 1 \quad \Rightarrow d = 33$$

  - Public key: $e : N = 17 : 55$; Private key: $d : N = 33 : 55$
- Why do this?
  - Because for $2 < \mathrm{K} < N - 1$, $\left(\mathrm{K}^e\ \%\ N\right)^d\ \%\ N = \mathrm{K}$
    - Exponentiating by e is encryption; exponentiating by d is decryption
  - This scheme is computationally expensive (i.e. slow)
    - Use for key establishment

RSA (simplified)



- Chuck and Sara *establish* $K = 6$ via *key transport*
  - They could use a DH *key agreement* instead

Structure

- $e = 17,\ d = 33,\ N = 55$ represents a binding relationship through

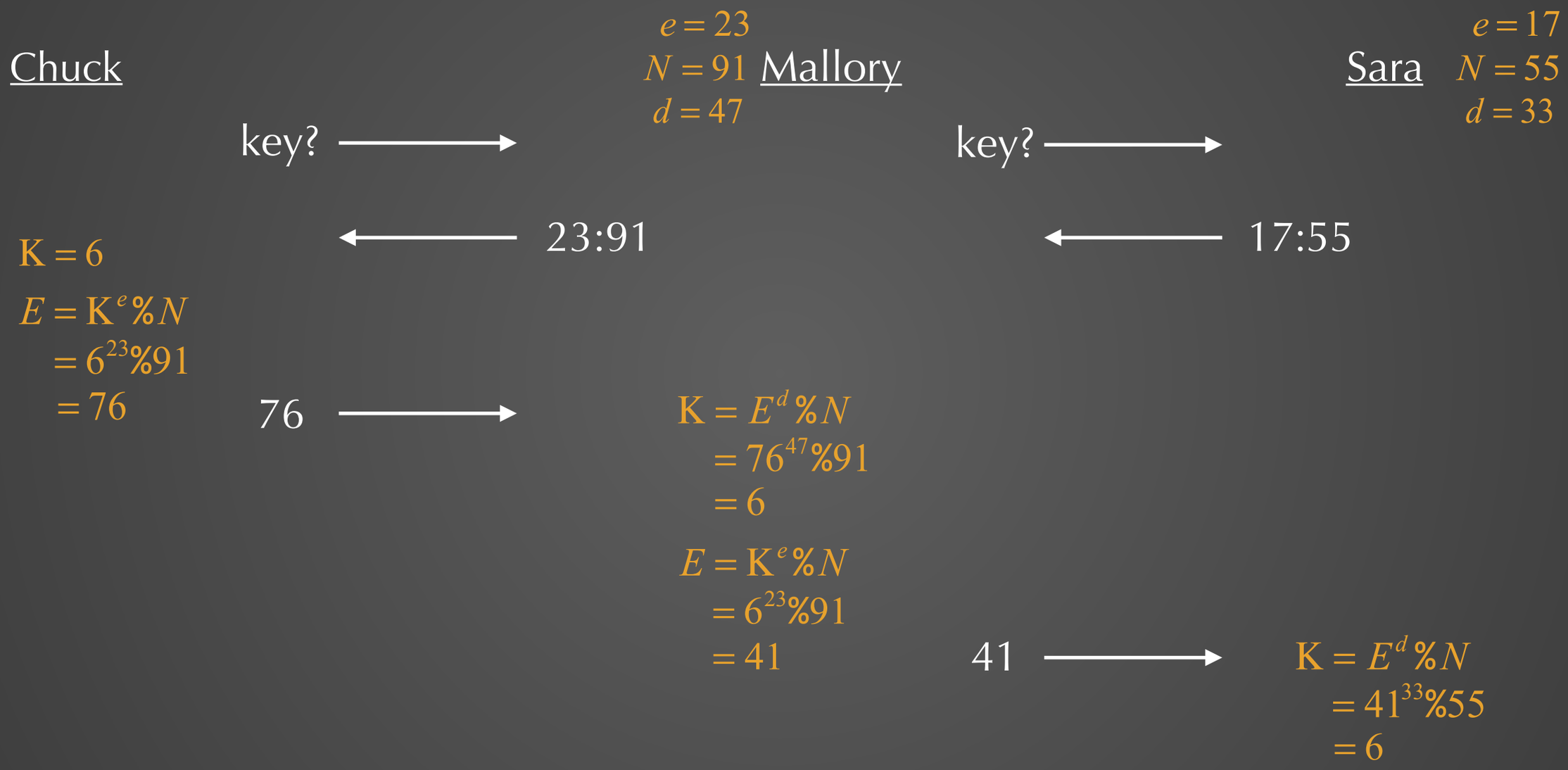
$$(e \cdot d)\ \%\ \varphi(N) = 1$$

- Given $e : N$ it is difficult* to determine d
- Chuck trusts $e : N$ belongs to Sara
  - Either explicitly or via transfer of trust
- Sara trusts she want to “talk” to Chuck
- Open system
  - Multiple entity trust model
  - No single control of who “talks” to whom

* The RSA problem is linked to the integer factorization problem

Man-in-the-Middle

Mallory creates a key pair: $p = 7,\ q = 13,\ N = 91,\ e = 23,\ d = 47$



- Mallory knows the value of the Chuck and Sara secret

CIA Document

Network Operations Division Cryptographic Requirements[1]

Section 2.4, 19

Any transport layer encryption[2] **must** be layered over the cryptography[3] discussed in this document. Because this outer layer may be decrypted by an attacker (e.g., SSL Man-in-the-Middle) any transport encryption **must** be used for traffic blending[4] only and not for secrecy.

1. Top-secret classified document obtained by Wikileaks through Shadow Brokers
2. TLS (e.g. HTTPS)
3. Application level security
4. Request metadata leaks no information

Scenario

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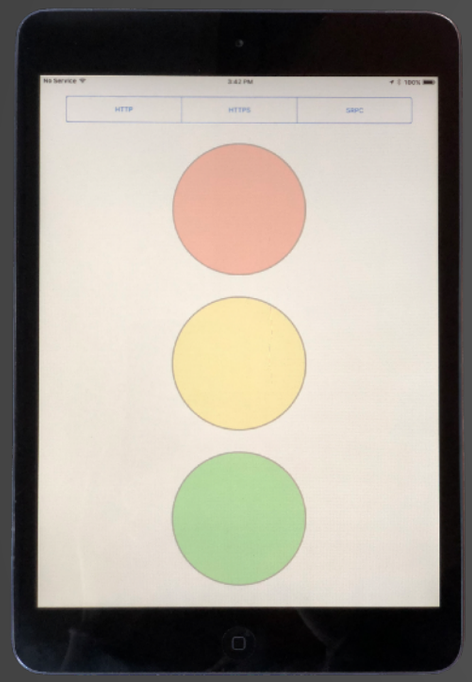
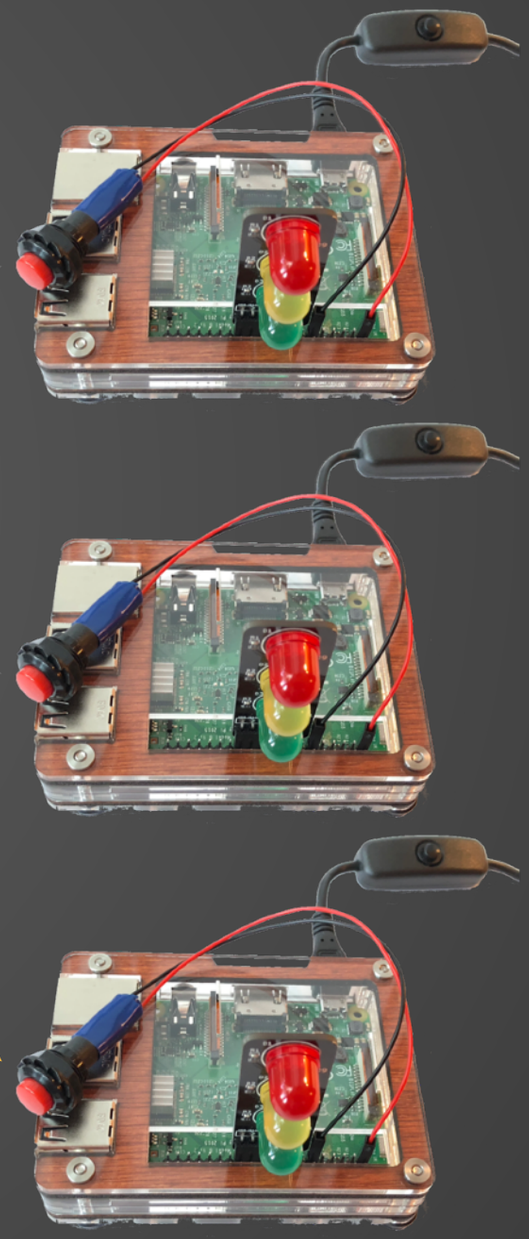


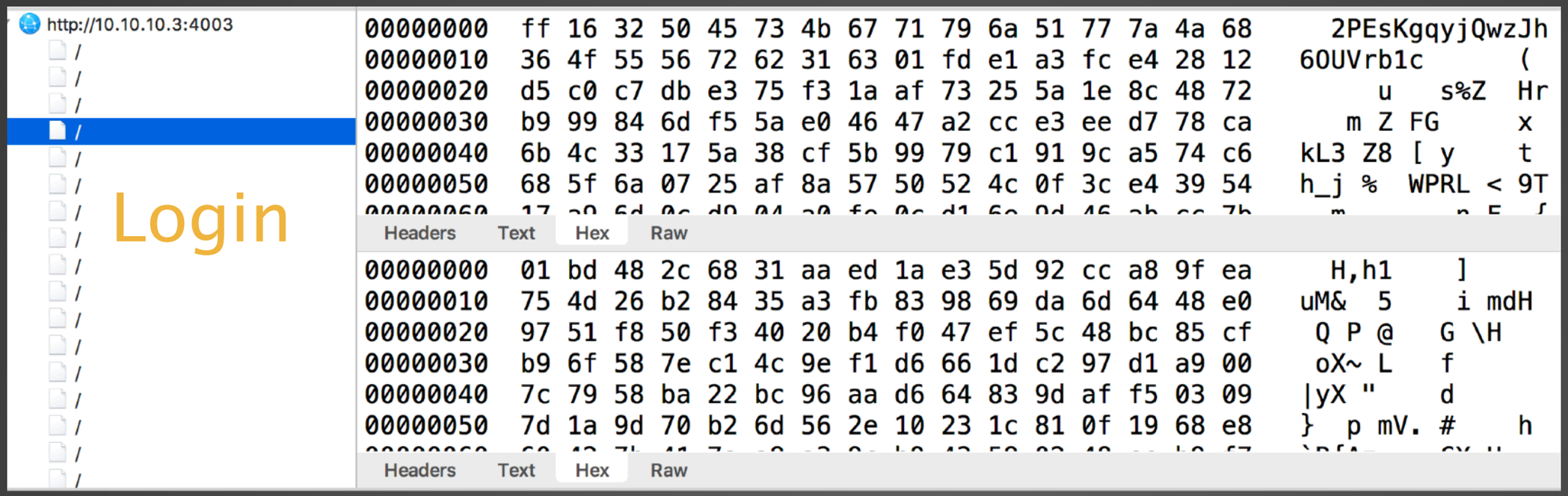
HTTP

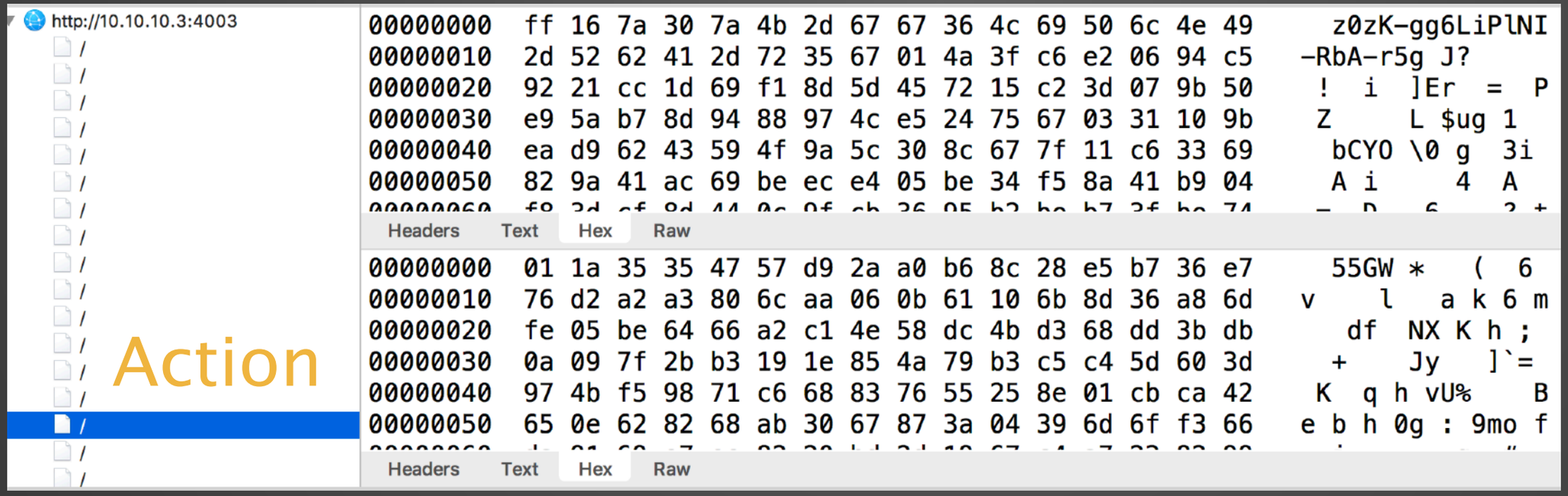
HTTPS

SRPC



SRPC






```
curl -d '{"action":"switch","light":"red"}' 'http://10.10.10.3:4001/light'
```

~~curl~~

SRP (simplified)

Chuck and Sara agree to use $g = 2, N = 13$ (public)

- Chuck chooses $x = 5$ and calculates $v = g^x \,\%\, N = 2^5 \,\%\, 13 = 6$
  - Chuck keeps $x = 5$ (secret) and gives $v = 6$ to Sara (verifier)

$x = 5$ Chuck			Sara $v = 6$
Random	$a = 11$		$b = 4$ Random
Computes	$A = g^a \,\%\, N = 2^{11} \,\%\, 13 = 7$	Id,7 →	
		← 9	$B = v + g^b \,\%\, N = 6 + 2^4 \,\%\, 13 = 9$ Computes
Computes	$\mathrm{K} = (B - g^x)^{a+x} \,\%\, N = (9 - 2^5)^{11+5} \,\%\, 13 = 3$		$\mathrm{K} = (Av)^b \,\%\, N = (7 \cdot 6)^4 \,\%\, 13 = 3$ Computes
Computes	$C_c = H(A \mid B \mid \mathrm{K}_c)$	Cc →	$C_c = H(A \mid B \mid \mathrm{K}_s)$ Checks
Checks	$C_s = H(A \mid C_c \mid \mathrm{K}_c)$	← Cs	$C_s = H(A \mid C_c \mid \mathrm{K}_s)$ Computes

- Chuck and Sara *establish* $\mathrm{K} = 3$ via *key agreement*

Structure

- $x = 5, v = 6, g = 2, N = 13$ represents a binding relationship through

$$v = g^x \,\%\, N$$

- Given $v : g : N$ it is difficult* to determine x
- Chuck and Sara *only trust each other*
  - Each holds a participating piece of the binding relationship
- Closed system
  - Single entity trust model
  - Explicit control over who “talks” to whom

* The SRP problem is linked to the Diffie-Hellman problem which is linked to the discrete logarithm problem

SRP & ALS

- Mutual client/server authentication
  - Ensures each “side” is communicating with a desired party
- Mutual user authentication
  - Ensures application is communicating on behalf of specific user
- Authentication via zero knowledge proof
  - Password never leaves client device
- Authentication and encryption in same layer
- Single entity trust mode
- Security orthogonal to API

SRPC

- Ephemeral keys with flexible session key management
  - Client initiated key refresh (manual or auto)
  - Auto-reconnect on first stale request (timed out session)
- Client-side key stretching
- Traffic blending
  - All request have same endpoint and meta-data (headers, etc.)
- Replay protection
  - Via nonces and (optional) timestamps
- Unicode normalization
  - Support credentials like τệ𝜎𝝉@𝛋ñöxện.î🤓 / ∂ïη𝛤ω∑𝑲¥

Key Exchange Options

- PAKE
  - SRP is an augmented PAKE
  - A slew of others
- Install server public key in client (and vice-versa)
  - Needham-Schroeder
  - Station-to-Station
  - A slew of others
- A slew of others

Is Security on Your Nerves?

Demo: GitHub Knoxen/SrpcWorld

Presentation: GitHub Knoxen/SecurityNerves

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