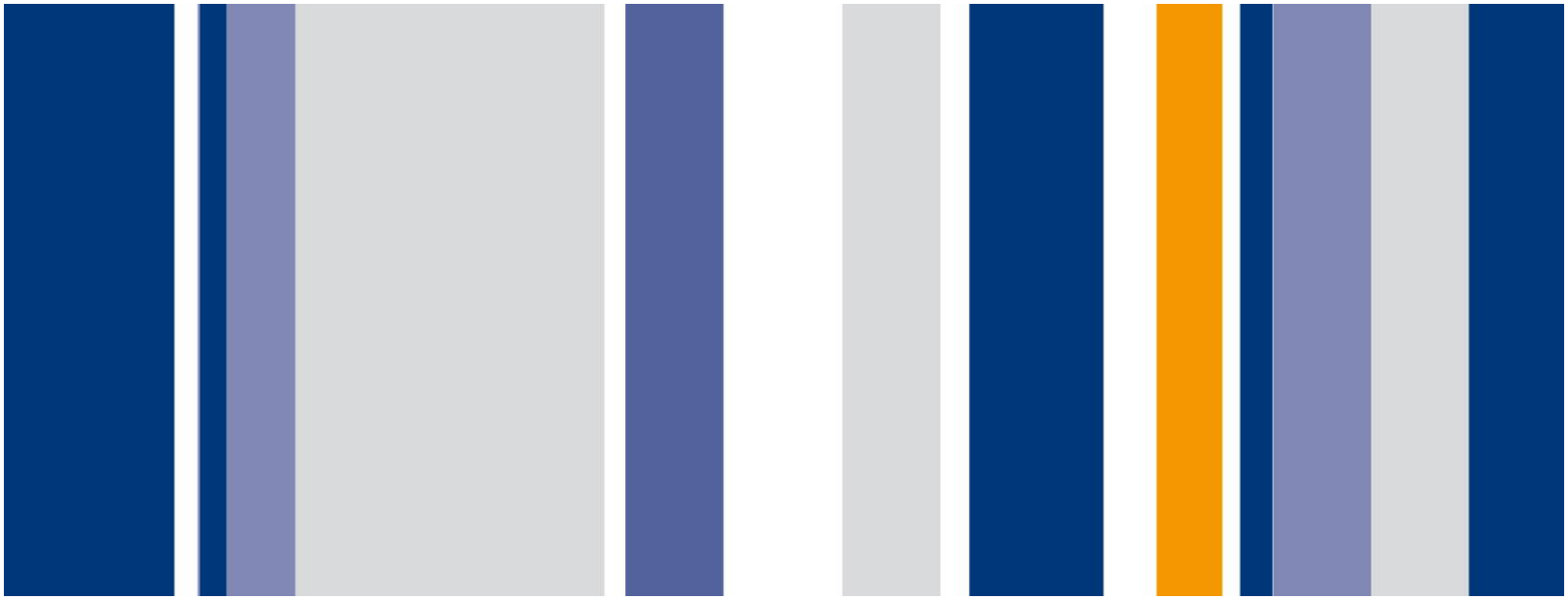
Security Testing 4G (LTE) Networks

44con
6th September 2012
Martyn Ruks & Nils



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Today's Talk

- Intro to 4G (LTE) Networks
- Technical Details
- Attacks and Testing
- Defences
- Conclusions

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Intro to 4G (LTE) Networks

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Mobile Networks

A Brief History Lesson

- 1G – 1980s Analogue technology (AMPS, TACS)
- 2G – 1990s Move to digital (GSM,GPRS,EDGE)
- 3G – 2000s Improved data services (UMTS, HSPA)
- 4G – 2010s High bandwidth data (LTE Advanced)



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Mobile Networks

Historic Vulnerabilities

- Older networks have been the subject of practical and theoretical attacks
- Examples include:
  - Ability to man in the middle
  - No perfect forward secrecy
  - No encryption on the back-end
- LTE Advanced addresses previous attacks



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Mobile Networks

Current Status of 4G

- Lots of 4G networks running or planned (eg Scandinavia, US)
- UK Trials have run in Cornwall, London etc
- Spectrum auction is important
- EE services launches soon!







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Mobile Networks

Why is 4G Important?



- Digital Britain strategy
- Fixed line broadband expensive in remote locations
- Provides high speed mobile data services
- High level of scalability on the back-end



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Technical Details

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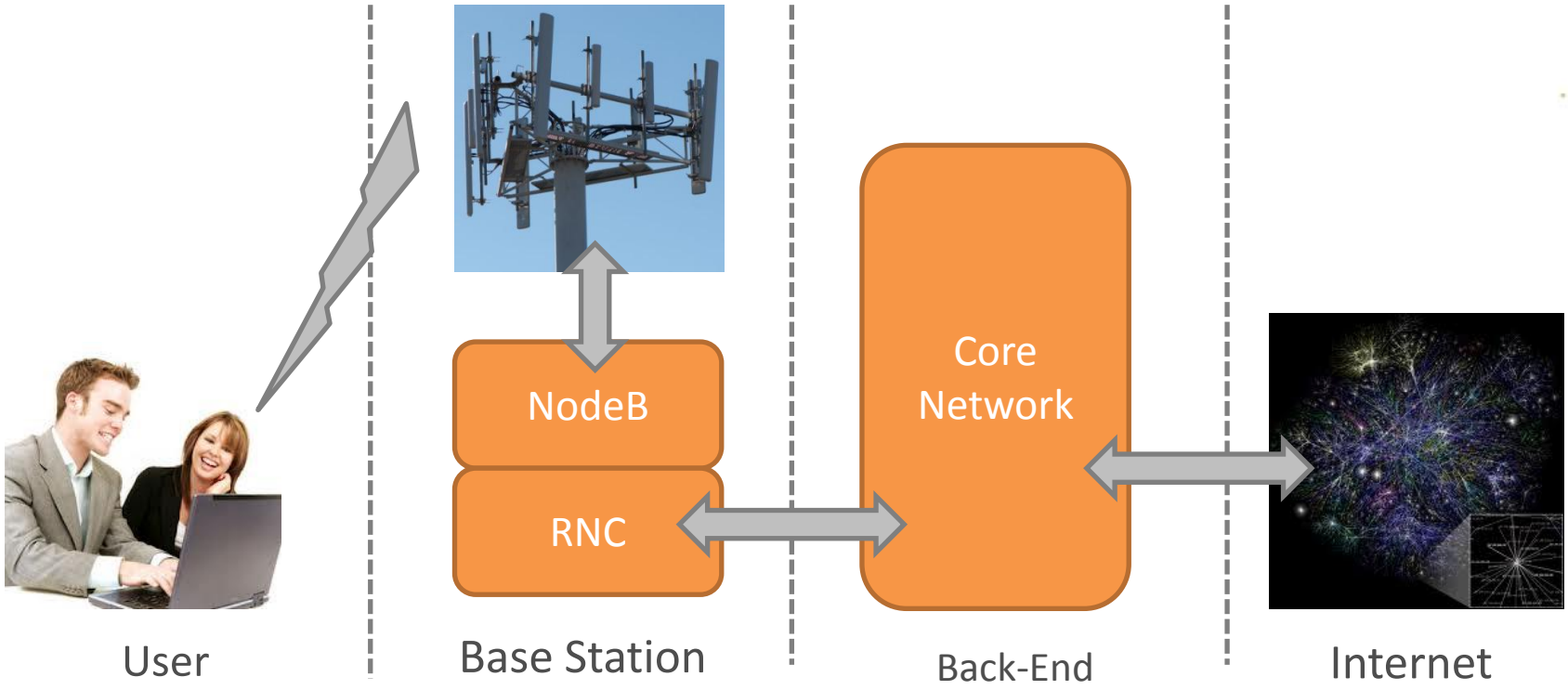
Conceptual View 3G



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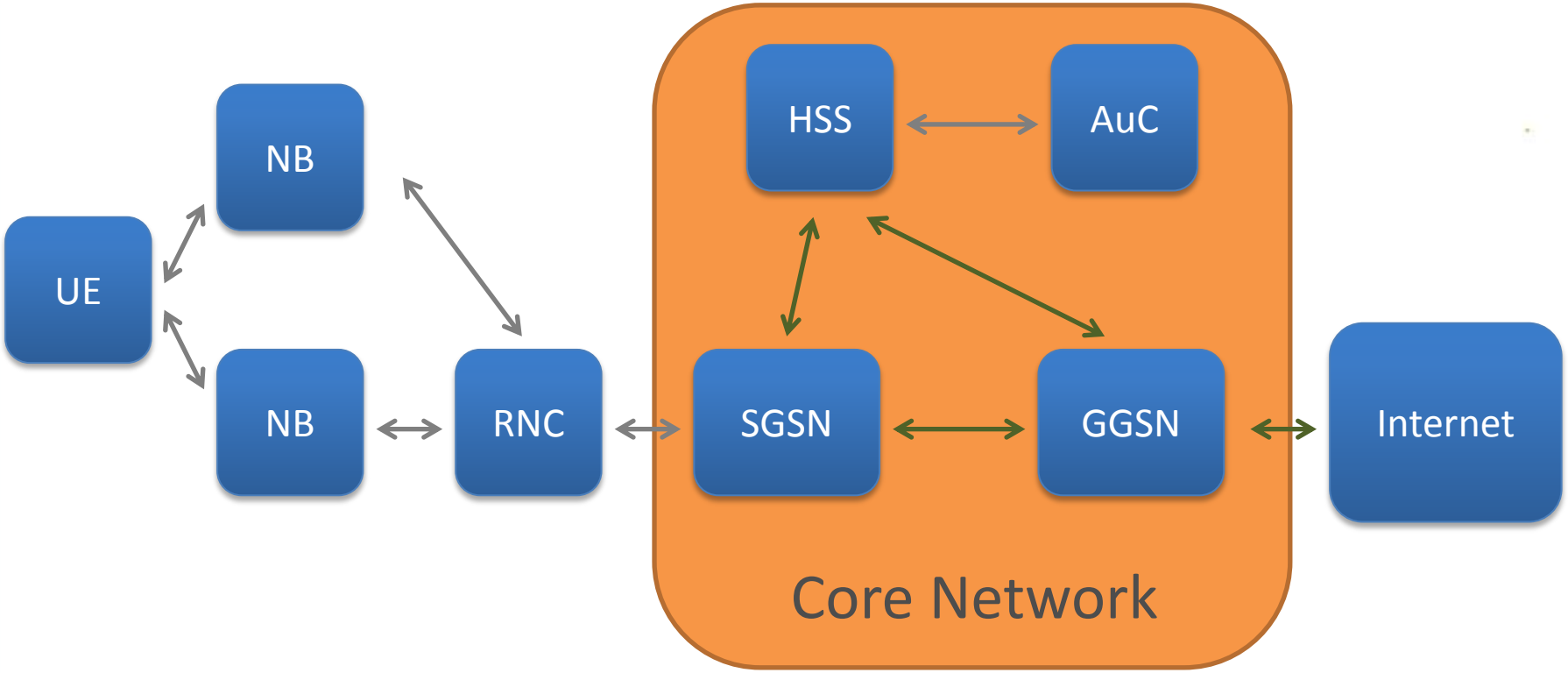
Network Overview 3G



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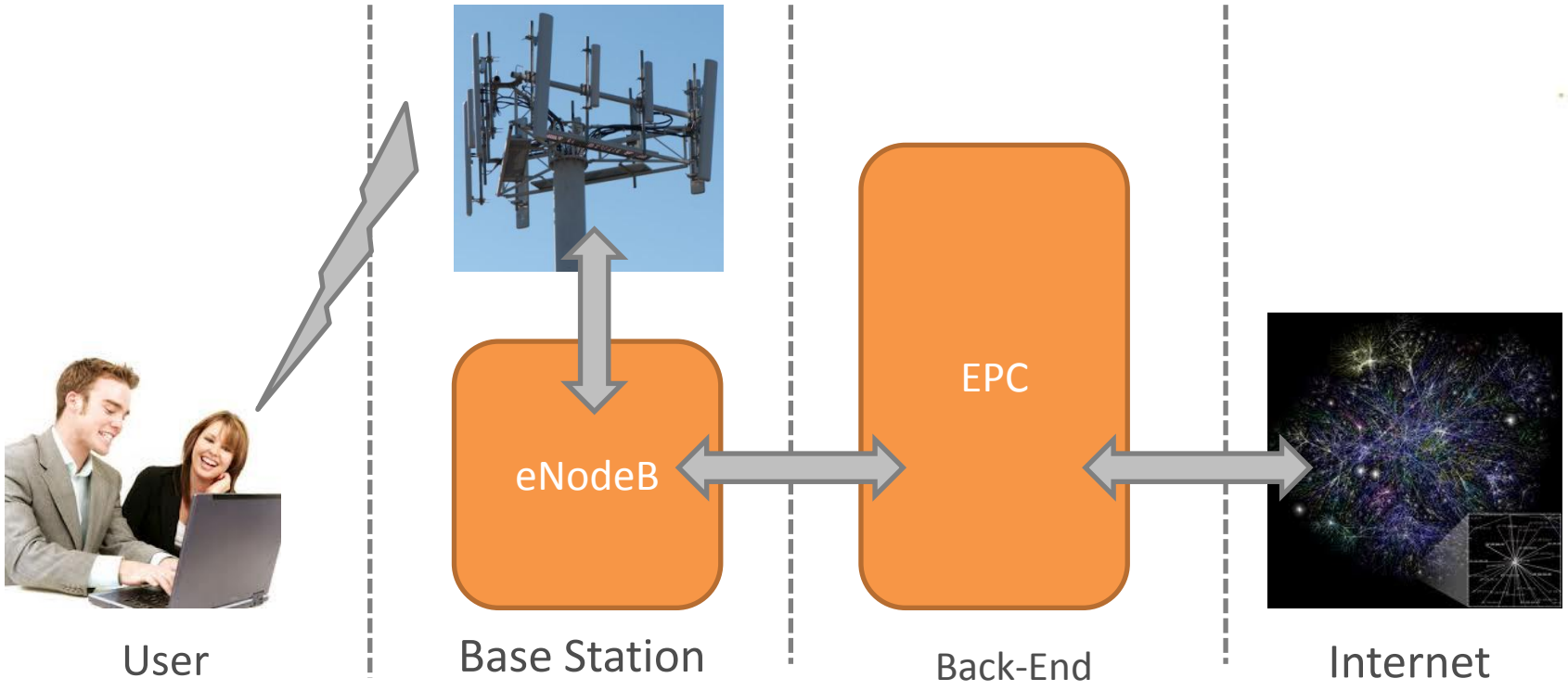
Conceptual View 4G



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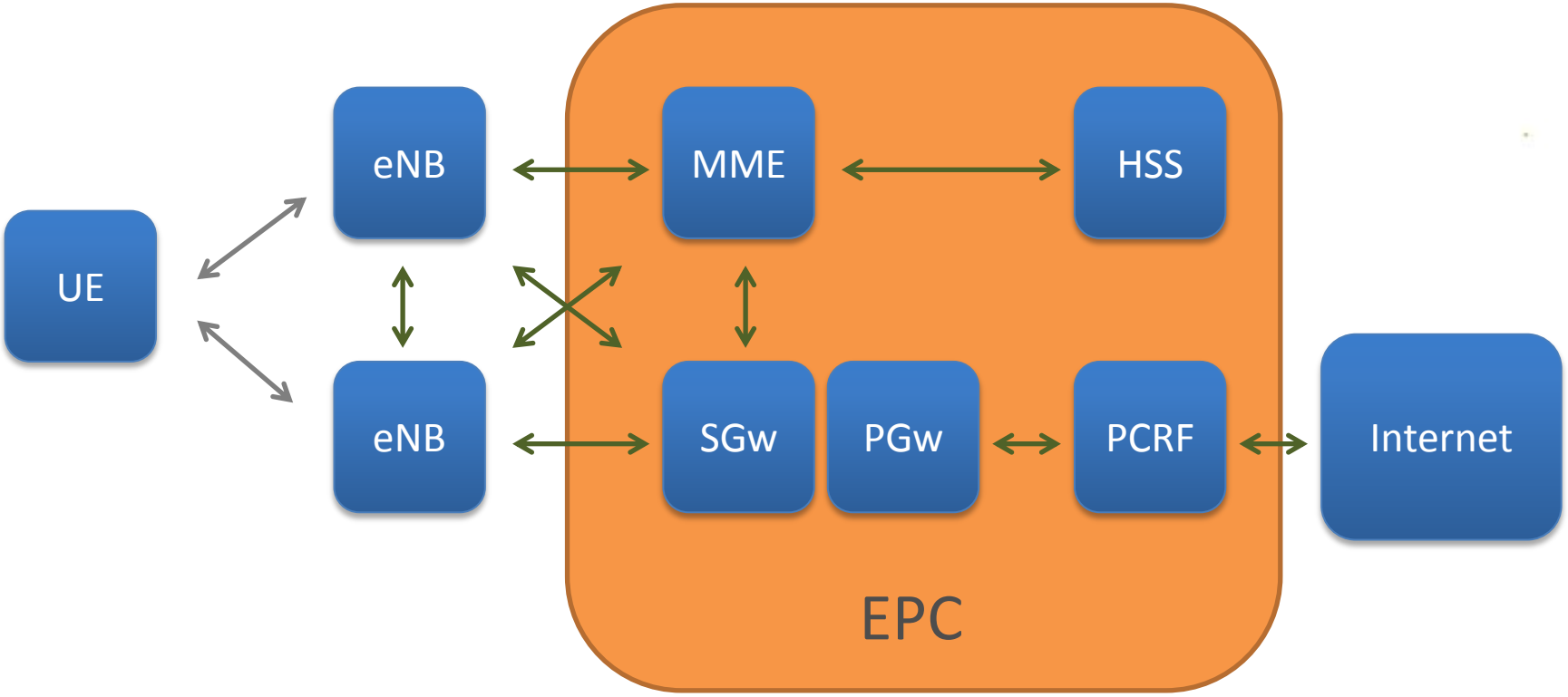
Network Overview 4G



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The Components

User Equipment (UE)

- What the customer uses to connect
- Mainly dongles and hubs at present
- Smartphones and tablets will follow (already lots in US)





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The Components

evolved Node B (eNB)

- The bridge between wired and wireless networks
- Forwards signalling traffic to the MME
- Passes data traffic to the PDN/Serving Gateway



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The Components

Evolved Packet Core (EPC)

- The back-end core network
- Manages access to data services
- Uses IP for **all** communications
- Divided into several components



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Mobile Management Entity (MME)

- Termination point for UE Signalling
- Handles authentication events
- Key component in back-end communications



The Components

Home Subscriber Service (HSS)

- Contains a user's subscription data (profile)
- Typically includes the Authentication Centre (AuC)
- Where key material is stored





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The Components

PDN and Serving Gateways (PGw and SGw)

- Handles data traffic from UE
- Can be consolidated into a single device
- Responsible for traffic routing within the back-end
- Implements important filtering controls



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The Components

Policy Charging and Rules Function (PCRF)

- Does what it says on the tin
- Integrated into the network core
- Allows operator to perform bandwidth shaping



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The Components

Home eNB (HeNB)

- The “FemtoCell” of LTE
- An eNodeB within your home
- Talks to the MME and PDN/Serving Gateway
- Expected to arrive much later in 4G rollout



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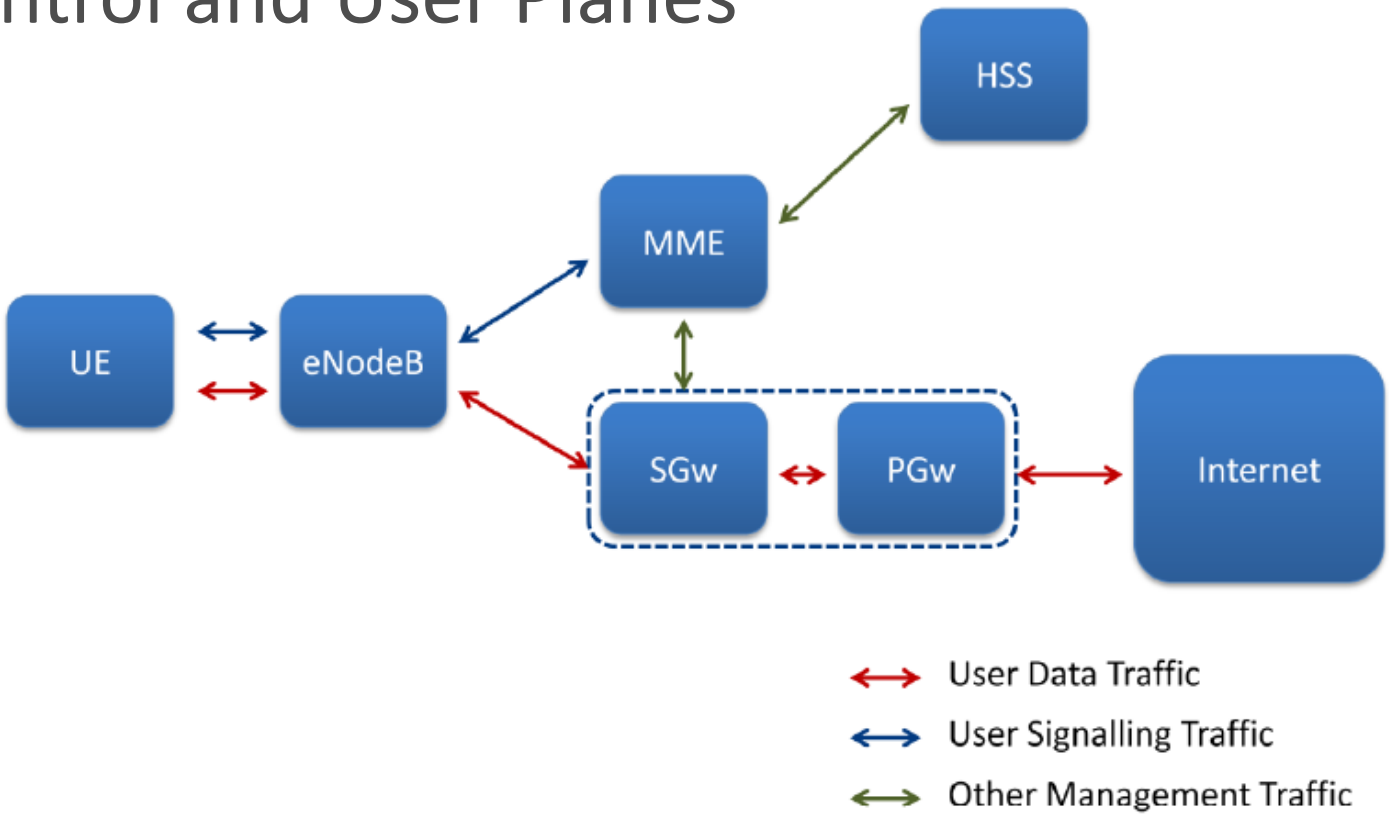
Network Overview

Control and User Planes



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The Protocols

Radio Protocols (RRC, PDCP, RLC)

- These all terminate at the eNodeB
- RRC is only used on the control plane
- Wireless user and control data is encrypted (some exceptions)
- Signalling data can also be encrypted end-to-end



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The Protocols

Internet Protocol (IP)

- Used by all back-end comms
- All user data uses it
- Supports both IPv4 and IPv6
- Important to get routing and filtering correct
- Common UDP and TCP services in use



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The Protocols - SCTP

- Another protocol on top of IP
- Robust session handling
- Bi-directional sessions
- Sequence numbers very important



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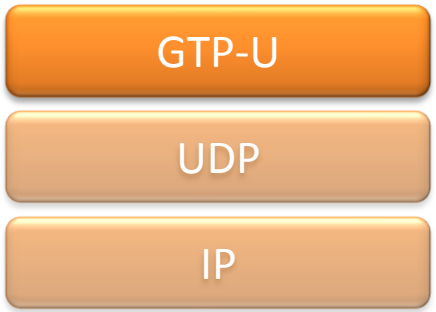
The Protocols – GTP-U

- Runs on top of UDP and IP
- One of two variants of GTP used in LTE
- This transports user IP data
- Pair of sessions are used identified by Tunnel-ID



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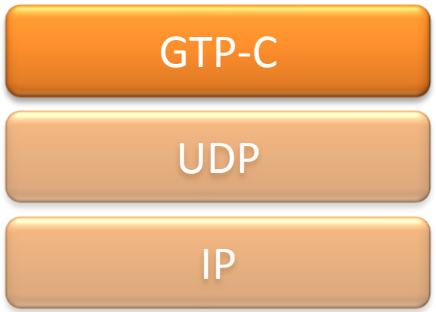
The Protocols – GTP-C

- Runs on top of UDP and IP
- The other variant of GTP used in LTE
- Used for back-end data
- Should not be used by the MME in pure 4G



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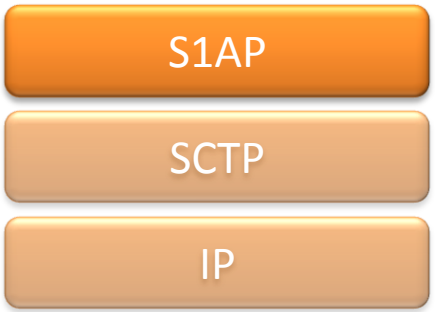
The Protocols

S1AP

- Runs on top of SCTP and IP
- An ASN.1 protocol
- Transports UE signalling
- UE sessions distinguished by a pair of IDs



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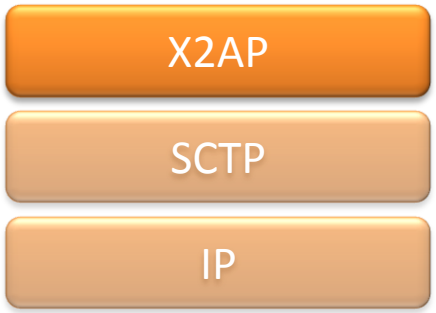
The Protocols

X2AP

- Very similar to S1AP
- Used between eNodeBs for signalling and handovers
- Runs over of SCTP and IP and is also an ASN.1 protocol



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Potential Attacks

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Targets for Testing

What Attacks are Possible

- Wireless attacks and the baseband
- Attacking the EPC from UE
- Attacking other UE
- Plugging into the Back-end
- Physical attacks (HeNB)

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Targets for Testing

Wireless Attacks and the Baseband

- A DIY kit for attacking wireless protocols is now closer (USRP based)
- Best chance is using commercial kit to get a head-start
- Not the easiest thing to attack



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Targets for Testing

Attacking the EPC from UE

- Everything in the back-end is IP
- You pay someone to give you IP access to the environment ☺
- Easiest place to start



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Targets for Testing

Attacking other UE

- Other wirelessly connected devices are close
- May be less protection if seen as a local network
- The gateway may enforce segregation between UE



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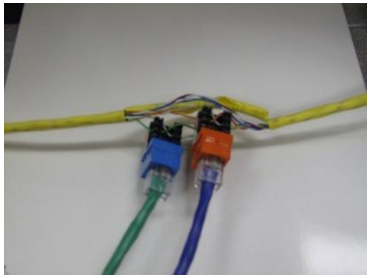
Targets for Testing

Wired network attacks

- eNodeBs will be in public locations
- They need visibility of components in the EPC
- Very easy to communicate with an IP network
- Everything is potentially in scope



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Targets for Testing

Physical Attacks (eNB)

- Plugging into management interfaces is most likely attack, except …
- A Home eNodeB is a different story
- Hopefully we have learned from the Vodafone Femto-Cell Attack



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What you can Test

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Tests to Run

As a Wirelessly Connected User

- Visibility of the back-end from UE
- Visibility of other UEs
- Testing controls enforced by Gateway
  - Spoofed source addresses
  - GTP Encapsulation (Control and User)

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Tests to Run

From the Back-End

- Ability to attack MME (signalling)
- Robustness of stacks (eg SCTP)
  - Fuzzing
  - Sequence number generation
- Testing management interfaces
  - Web consoles
  - SSH
  - Proprietary protocols

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Tests to Run

Challenges

- Spoofing UE authentication is difficult
- Messing with radio layers is hard
- ASN.1 protocols are a pain
- Injecting into SCTP is tough
- Easy to break back-end communications

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Tests to Run

S1AP Protocol

- By default no authentication to the service
- Contains eNodeB data and UE Signalling
- UE Signalling can make use of encryption and integrity checking
- If no UE encryption is used attacks against connected handsets become possible

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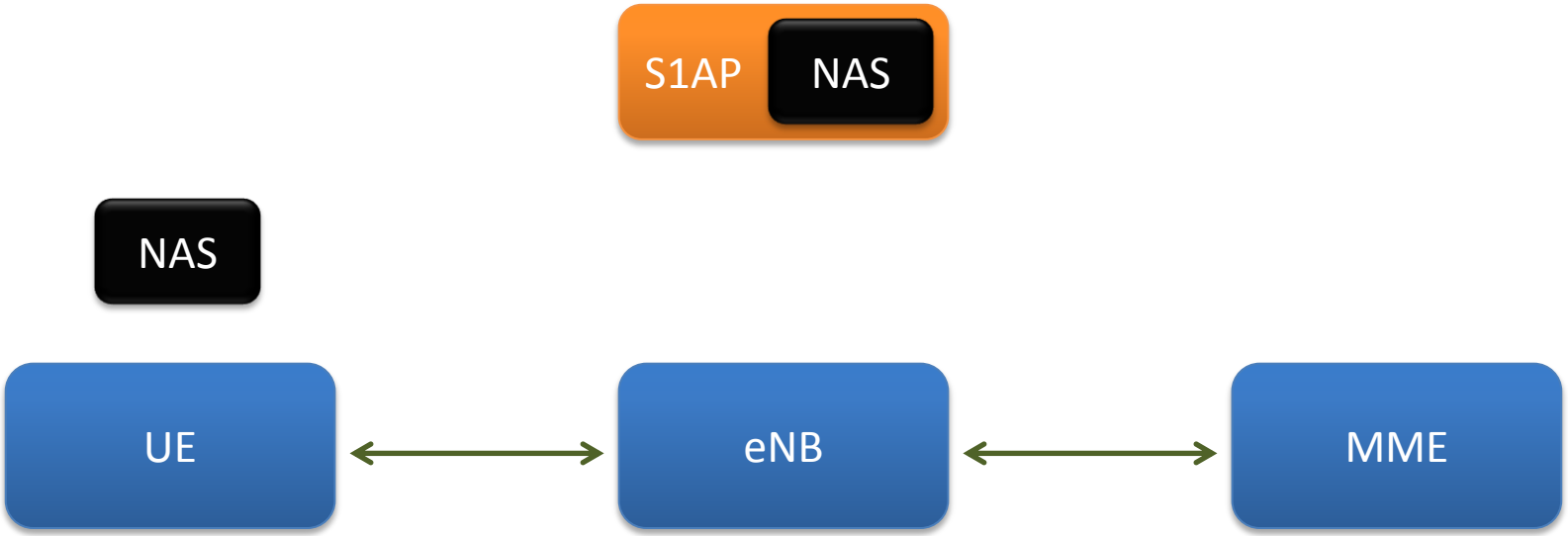
S1AP and Signalling



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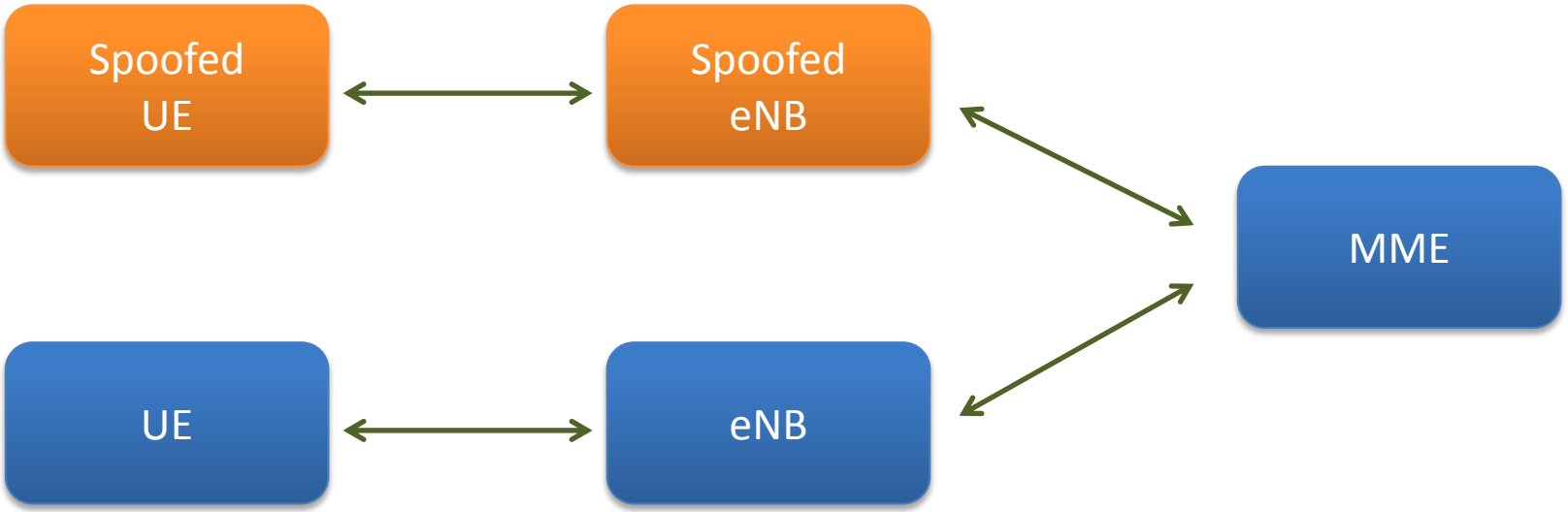
Tests to Run

S1AP and Signalling



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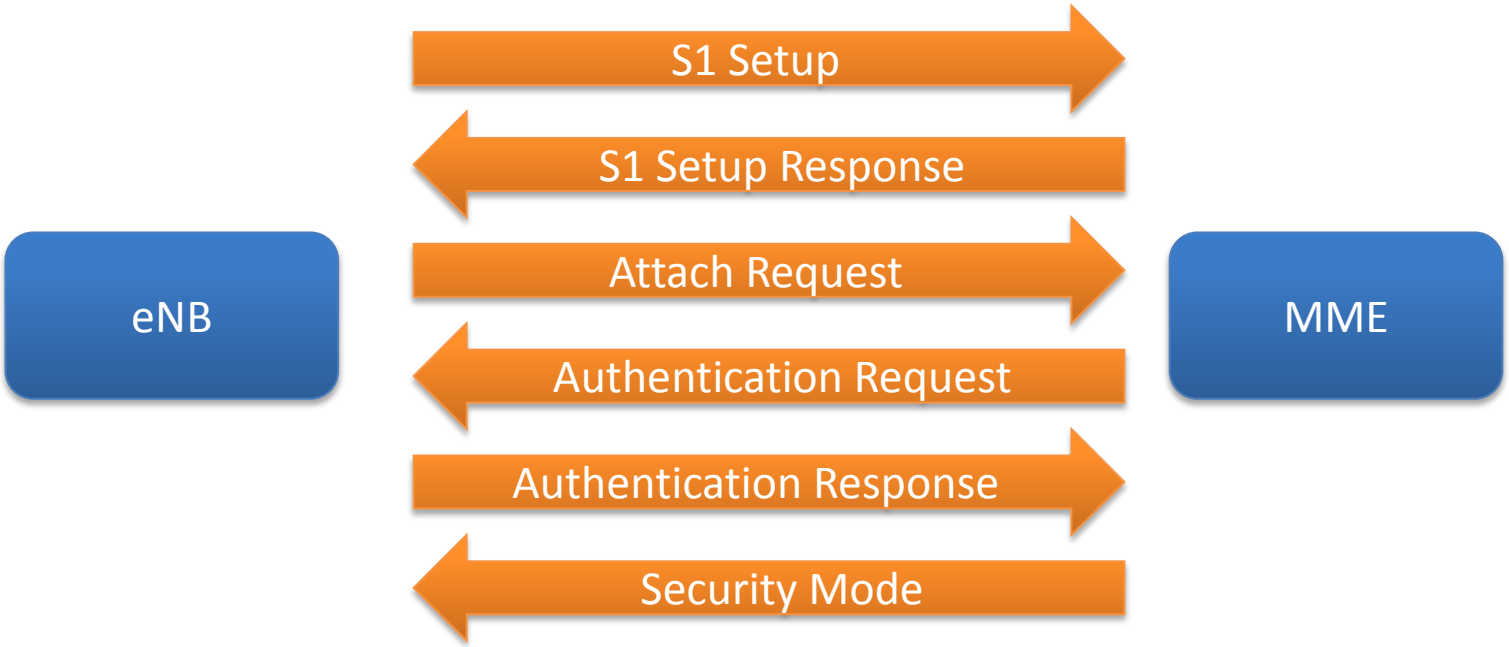
Tests to Run

S1AP and Signalling



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Tests to Run

GTP Protocol

- Gateway can handle multiple encapsulations
- It uses UDP so easy to have fun with
- The gateway needs to enforce a number of controls that stop attacks

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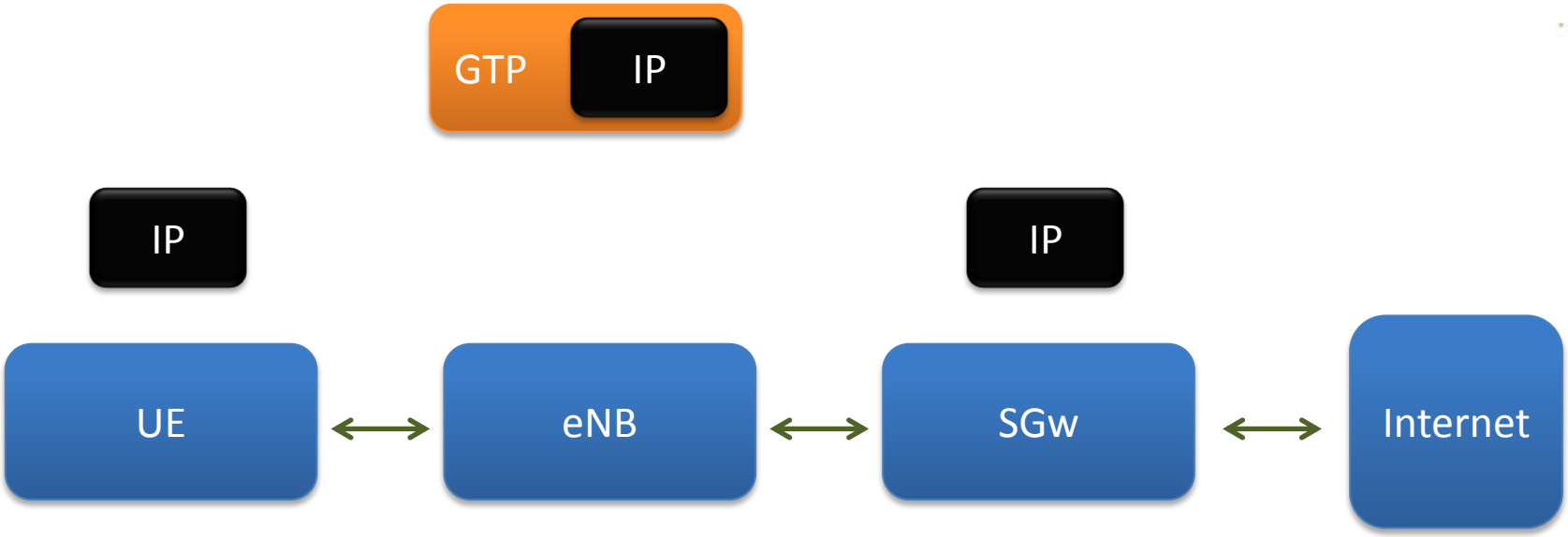
GTP and User Data



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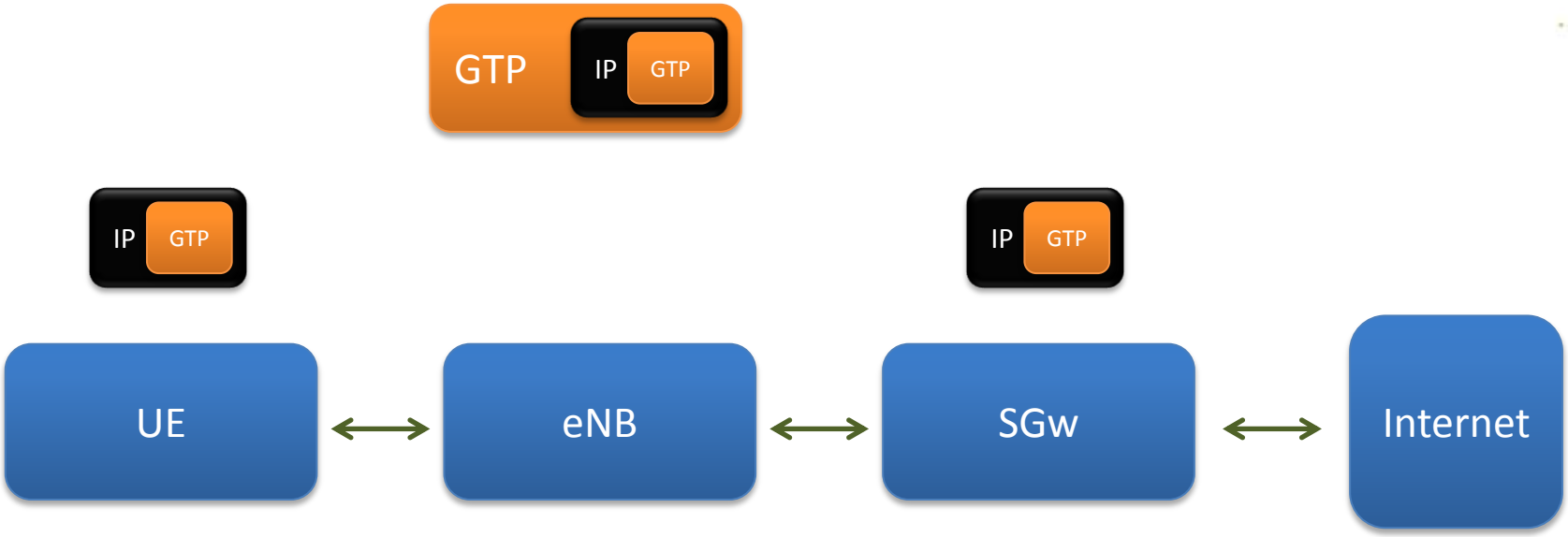
Tests to Run

GTP and User Data



GTP and User Data



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Tests to Run

GTP and User Data

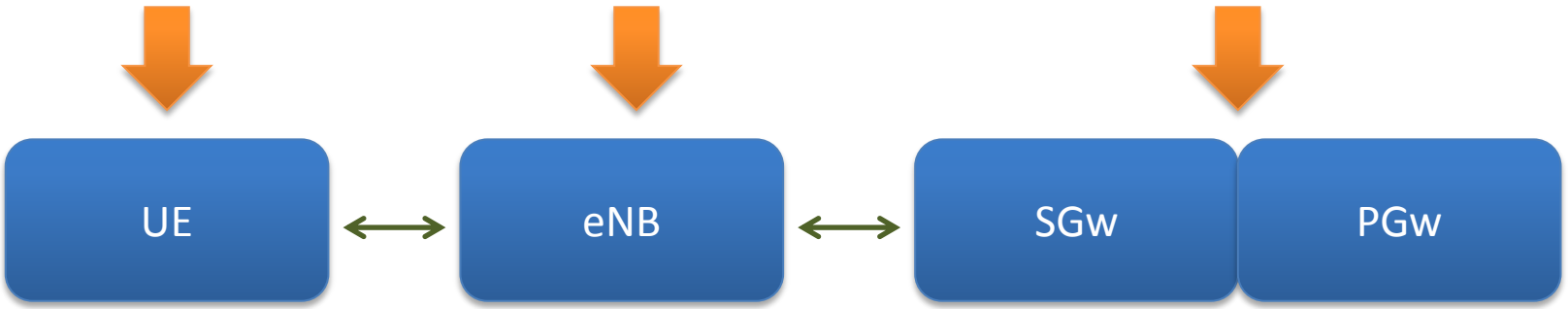
Destination IP Address (IP)

GTP Tunnel ID (GTP)

Source IP Address (GTP)

Source IP Address (IP)

Invalid IP Protocols (IP)



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Tests to Run

Old Skool

- Everything you already know can be applied to testing the back-end
- Its an IP network and has routers and switches
- There are management services running

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Defences

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Defences

The Multi-Layered Approach

- Get the IP network design right
- Protect the IP traffic in transit
- Enforce controls in the Gateway
- Ensure UE and HeNBs are secure
- Monitoring and Response
- Testing

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Defences

Unified/Consolidated Gateway

- The “Gateway” enforces some very important controls:
  - Anti-spoofing
  - Encapsulation protection
  - Device to device Routing
  - Billing and charging of users

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Defences

IP Routing

- Architecture design and routing in the core is complex
- Getting it right is critical to security
- We have seen issues with this
- This must be tested before an environment is deployed

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Defences

IPSec

- If correctly implemented will provide Confidentiality and Integrity protection
- Can also provide authentication between components
- Keeping the keys secure is not trivial and not tested

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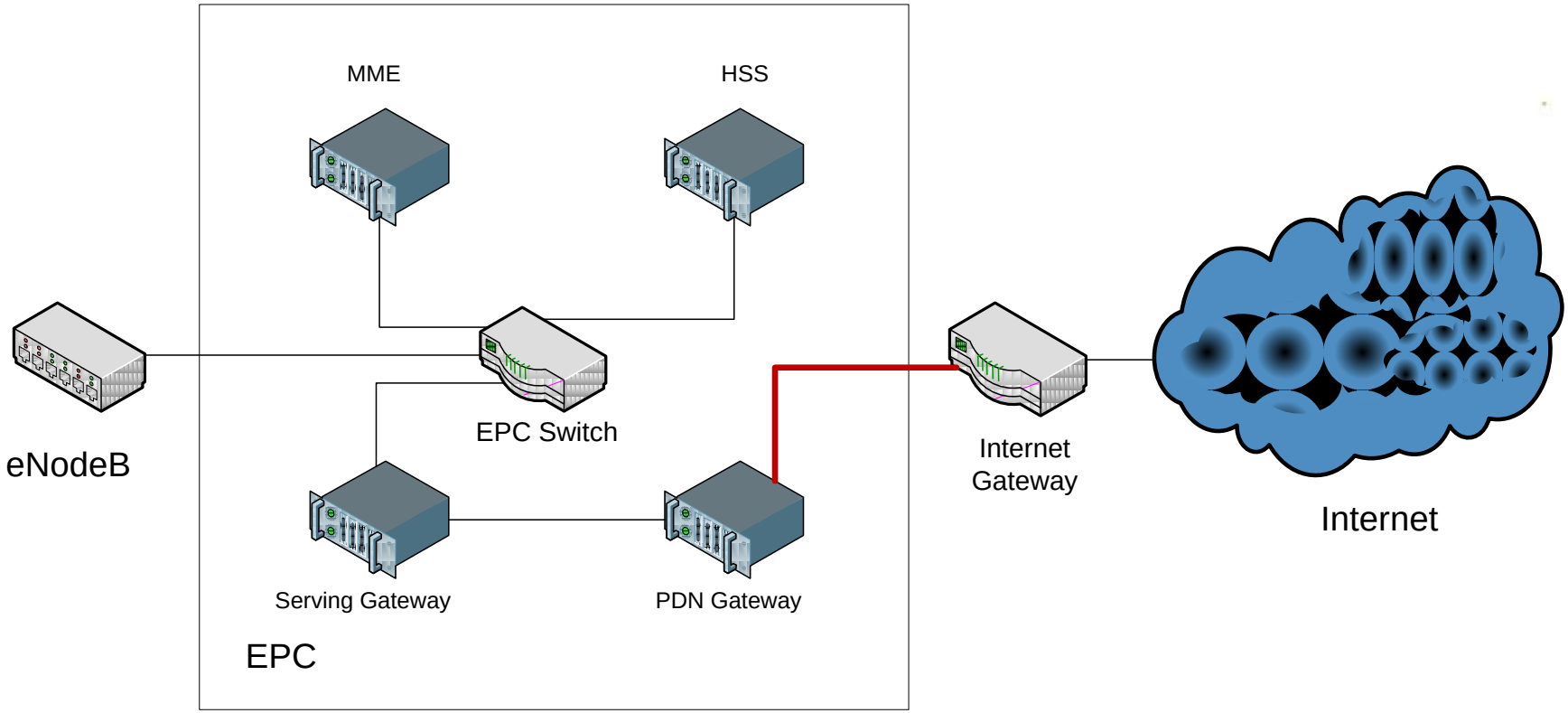
Architecture Consideration



Conclusions

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Conclusion 1

- There are 3 key protective controls that should be tested within LTE environments
  - Policies and rules in the Unified/Consolidated Gateway
  - The implementation of IPSec between all back-end components
  - A back-end IP network with well-designed routing and filtering

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Conclusion 2

- Despite fears from the use of IP in 4G, LTE will improve security if implemented correctly
  - The 3 key controls must be correctly implemented
  - Testing must be completed for validation
  - Continued scrutiny is required
  - Legacy systems may be the weakest link

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Conclusion 3

- Protecting key material used for IPSec is not trivial
  - The security model for IPSec needs careful consideration
  - Operational security processes are also important
  - Home eNodeB security is a challenge

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Conclusion 4

- More air interface testing is needed
  - Will need co-operation from vendors/operators
  - “Open” testing tools will need significant development effort
  - Still lower hanging fruit if support for legacy wireless standards remain

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Questions



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