4G / 5G Open Source Cores

Current & Future States

June 27, 2019

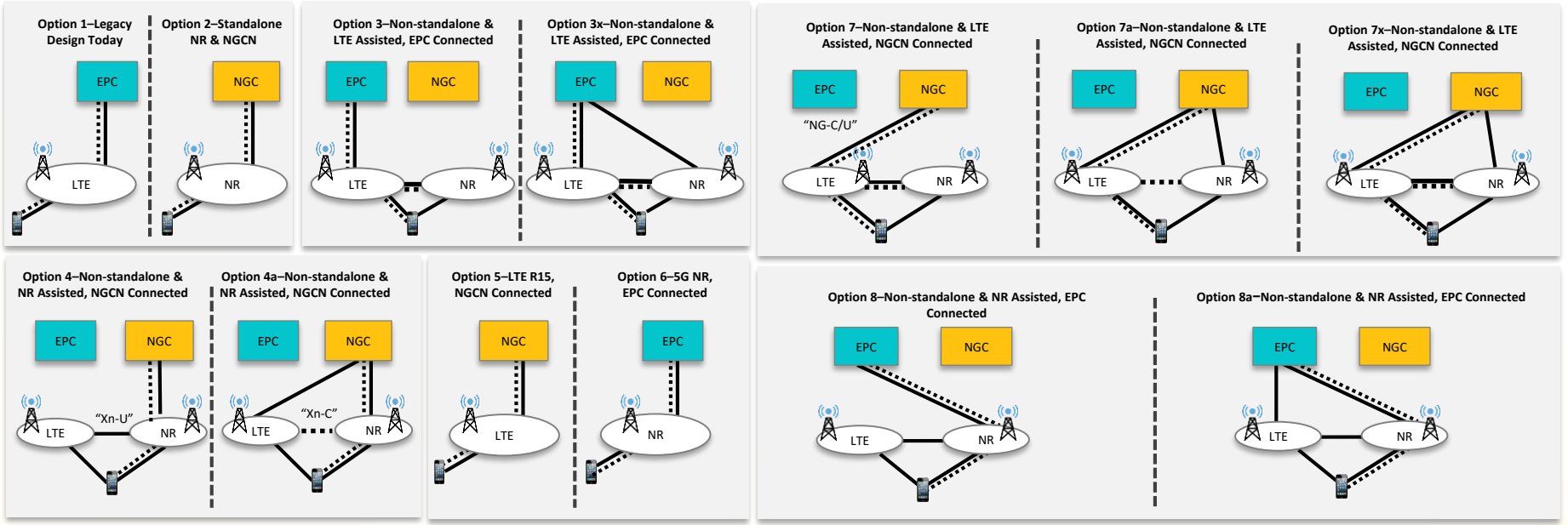
OAI NA Workshop

Current Open Source Efforts

- EPC based
  - Makes sense given Release 15 just finished its 1.3 ASN.1 release
  - Scope of Release 15 is a start but not parity with 4G
  - Device & Production hardware availability
- Current efforts (major ones)
  - openair
  - magma
  - omec

Deployment Options

Intentional Squint Chart

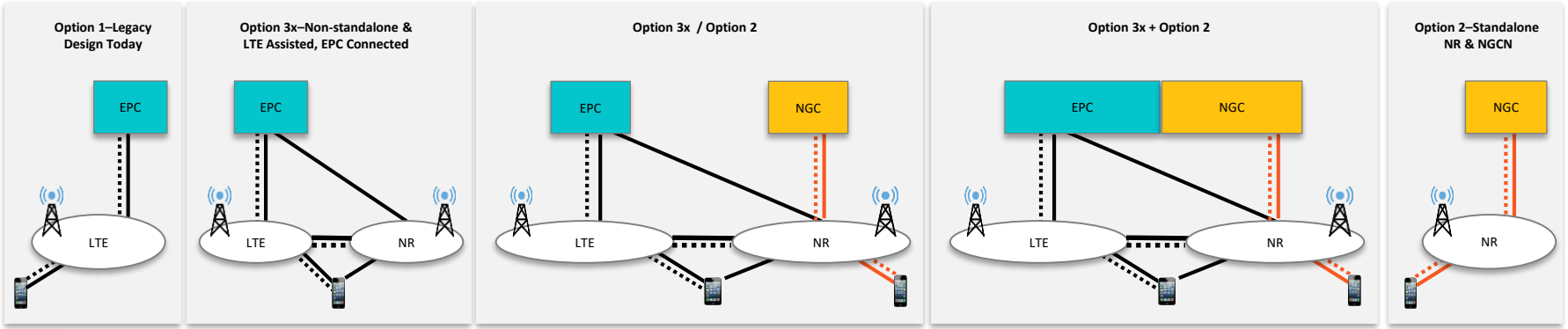


Dashed Line – Control

Solid Line - User

Migration

Just picking on Option 3x ….



LTE only devices
EN-DC devices

LTE only devices
EN-DC devices
NR only devices

Latest Trend – NGC NF + EPC NF
All previous devices + NR with LTE fallback

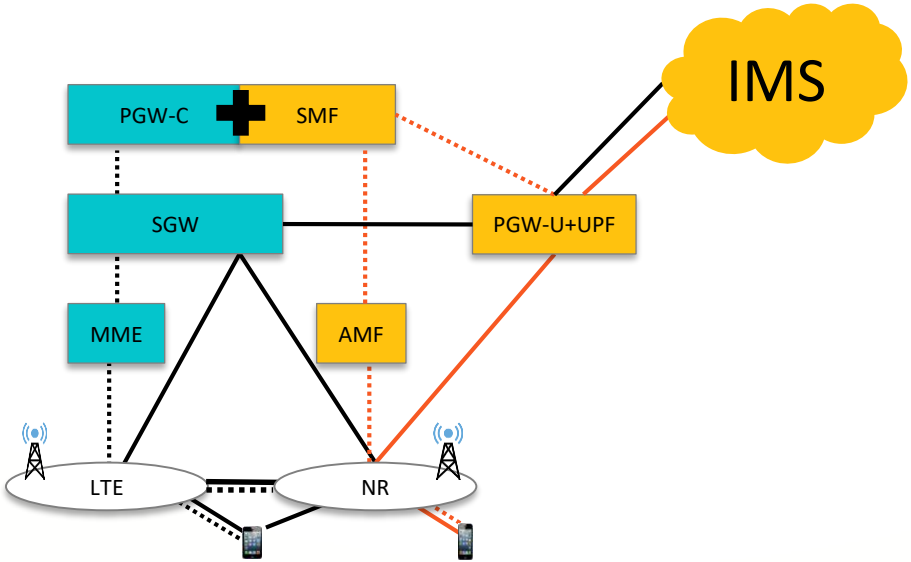
When?

Colors
Red – NR only
Black – LTE, LTE+NR

Line Type
Dashed – Control
Solid - User

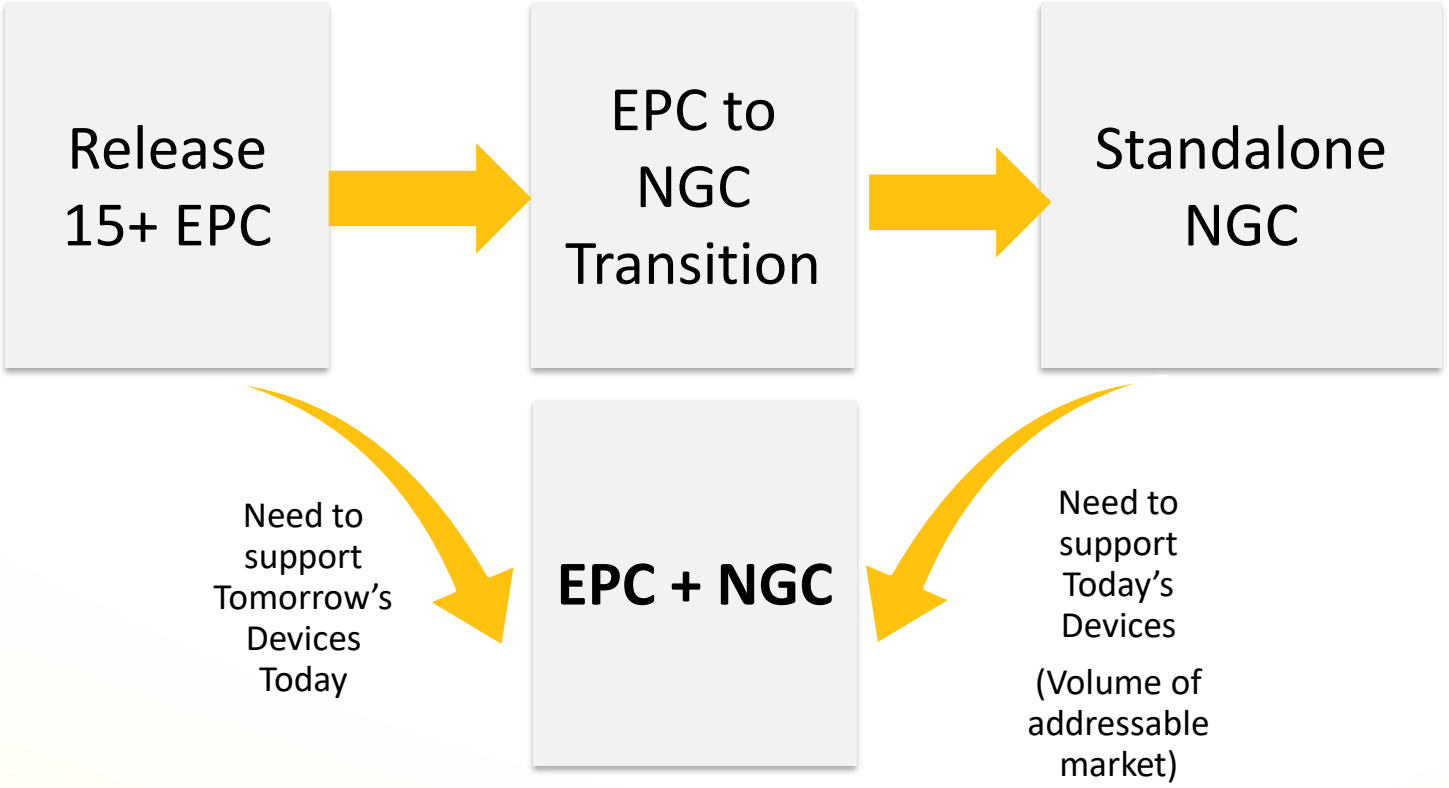
The ‘+’ VoNR with VoLTE fallback

Only relevant components shown



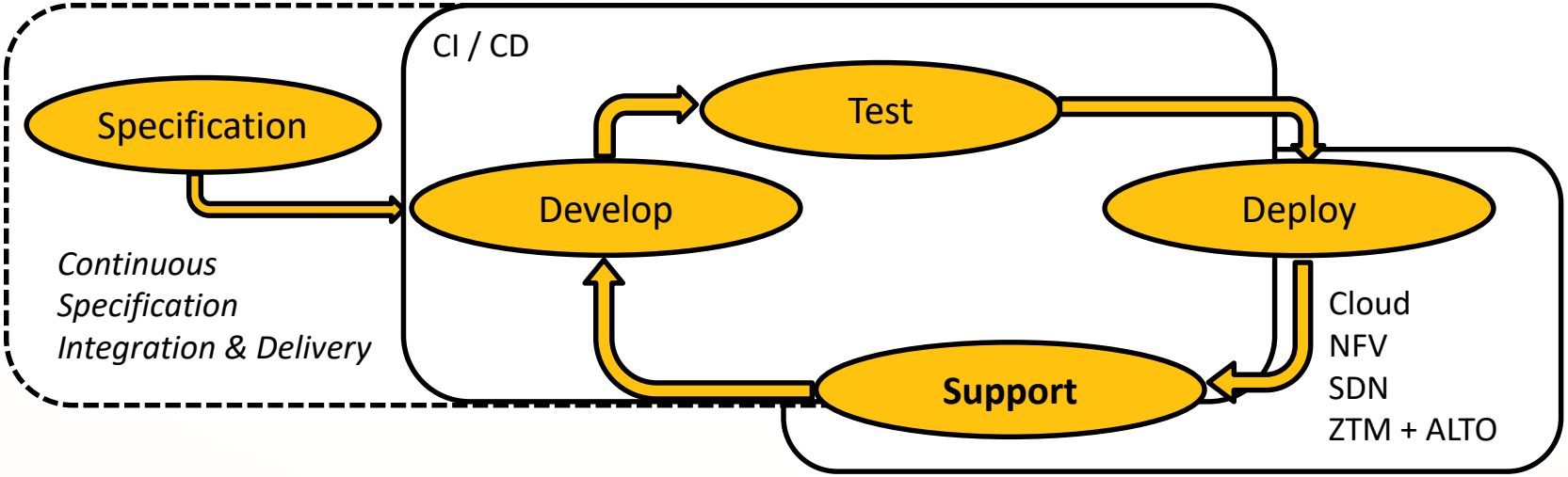
Colors	Line Type
Red – NR only	Dashed – Control
Black – LTE, LTE+NR	Solid - User

So if you are developing a core....



Constructing a Core for 4G + 5G

Deployment is being tackled by many, focus on functionality!



Continuous Specification Integration & Delivery (CSI/D)

Integrate as much as we can as early as possible (from specification stage)

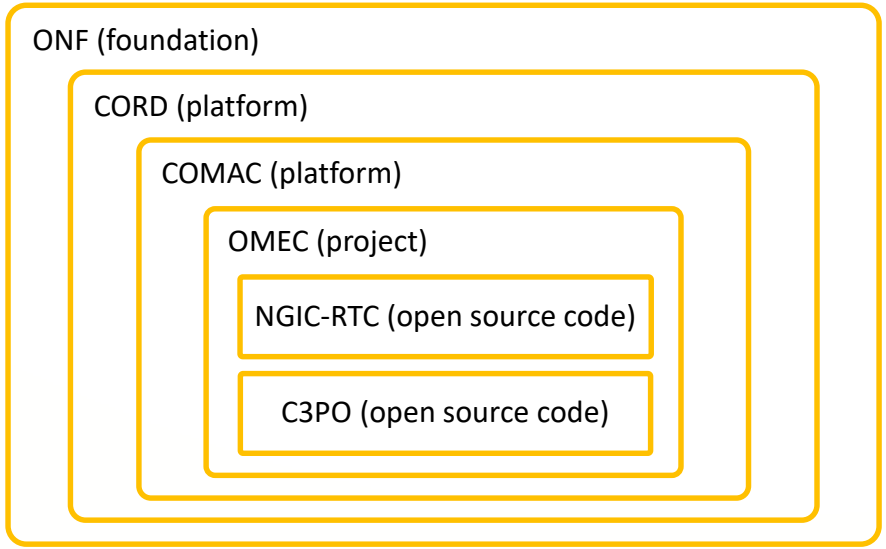
- Not a new idea

Tenets:

- QA (code, performance, security, compliance) is required at every step!
- Look for operational (design) patterns
- Look for development patterns
- The framework will change over time (including languages and supporting technologies, e.g. VMs, cloud etc.)
- Make it efficient, reliable, scalable, available and repeatable!
- Automate where you can; develop if you must!

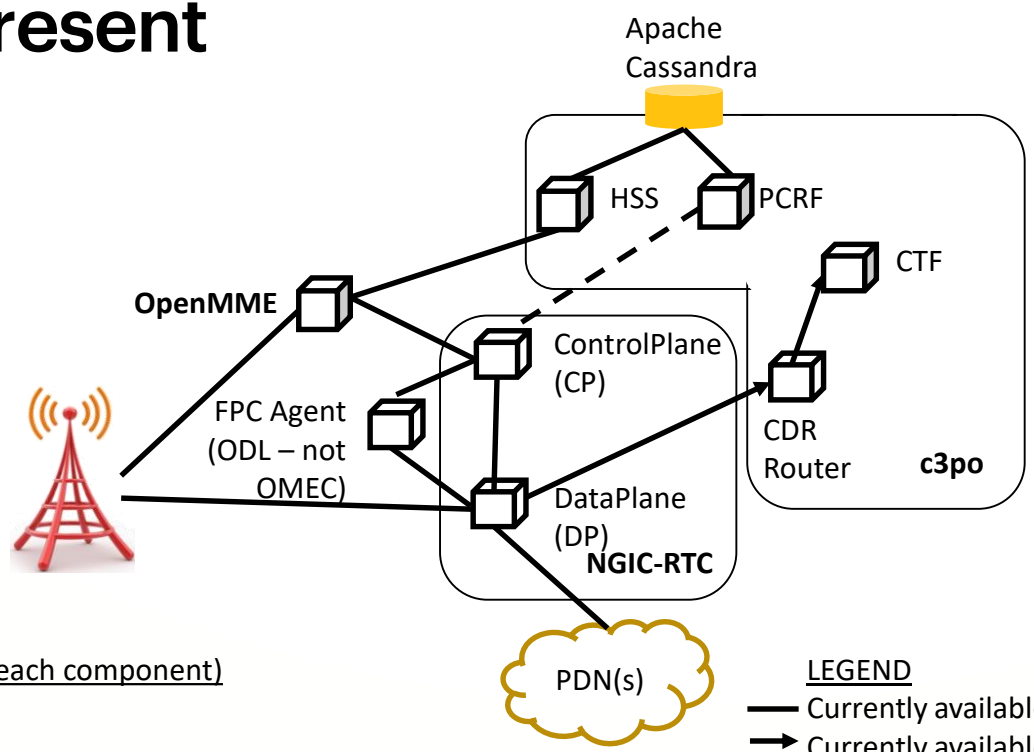
The ONF Open Mobile Evolved Core (OMEC) is where we realize many of these ideas.

OMEC's Place in the ONF



OMEC – Present

Visible Projects



<u>Single Frame (1 instance of each component)</u>
40K Users
1K Control Plane TPS
42-80 CPU Cores

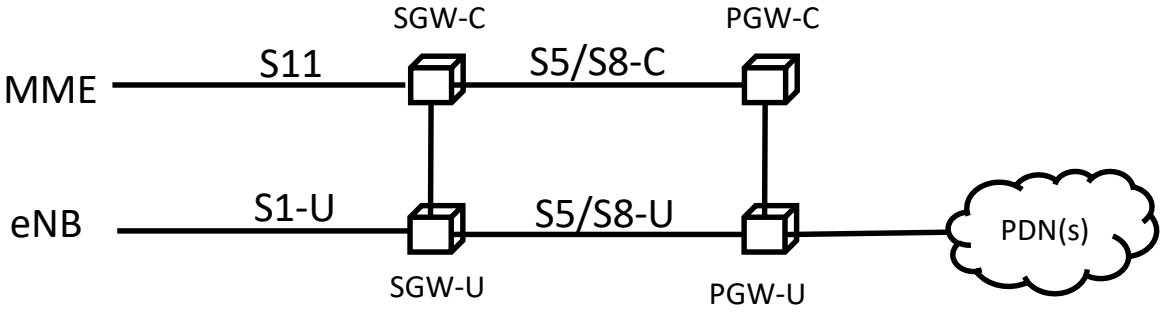
<u>LEGEND</u>
Currently available
Currently available (& unidirectional)
Work in progress

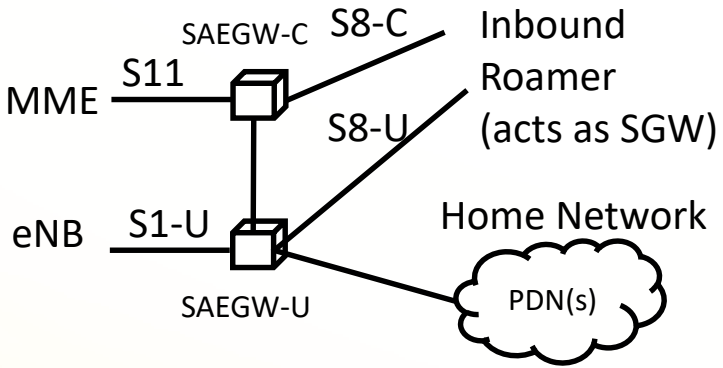
Note HSS supports IoT interfaces including S6t

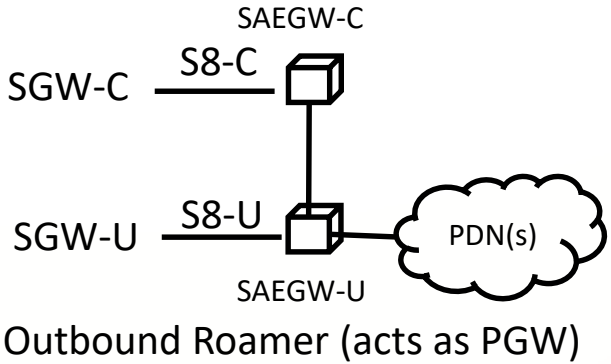
Features

Now	Under Test (NGIC)	Next (NGIC)
• Default Bearers • Offline Billing secured by SGX • Child Protections (gating by domain or 5 tuple) • Basic MME support (initial attach, detach, etc.)	• GTP-C structure (auto generated) • PFCP structure (auto generated) • SGW, PGW, SAEGW roles • UPF lookup via DNS with Dedicated Core & Network Capability Support • CLI client to REST interface • REST interface for CLI and remote operation	• All TS 23.214-f40 Stage 2 Procedures that use S11 GTP with GTP based mobility • All SGW, PGW, SAEGW restoration procedures (TS 23.007) • Operational Measurements (via logs) • Alarms (via logs)

Roles





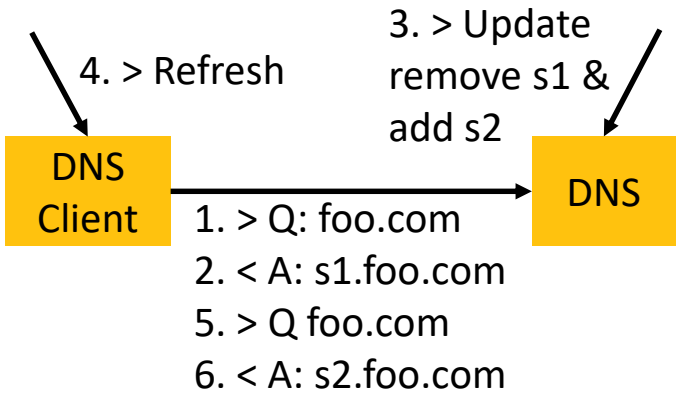


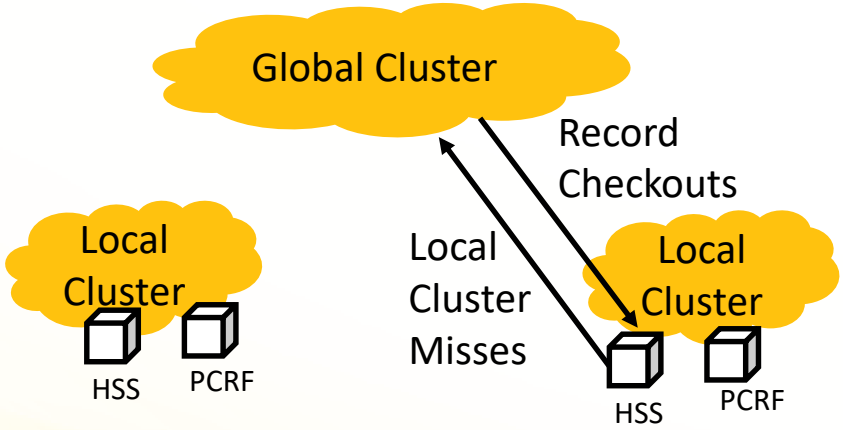
Outbound Roamer (acts as PGW)

Interesting Functions

DNS query tracking & refresh (API access under development)

- DNS client remembers the queries associated with answers
- Can automatically refresh based upon timers or commands
- Grow / contract following TS 29.303 (DDDS) and remain in sync with Orchestration decisions





2B+ Entries (design phase)

- Local Cluster (2B keys per space)
  - Holds individual records
  - Lists
- Global Cluster (2B key ranges per space)
  - checkout based
  - Each entry is a range of records

OMEC CI / CD

OMEC CI/CD is on github (https://github.com/omec-project)

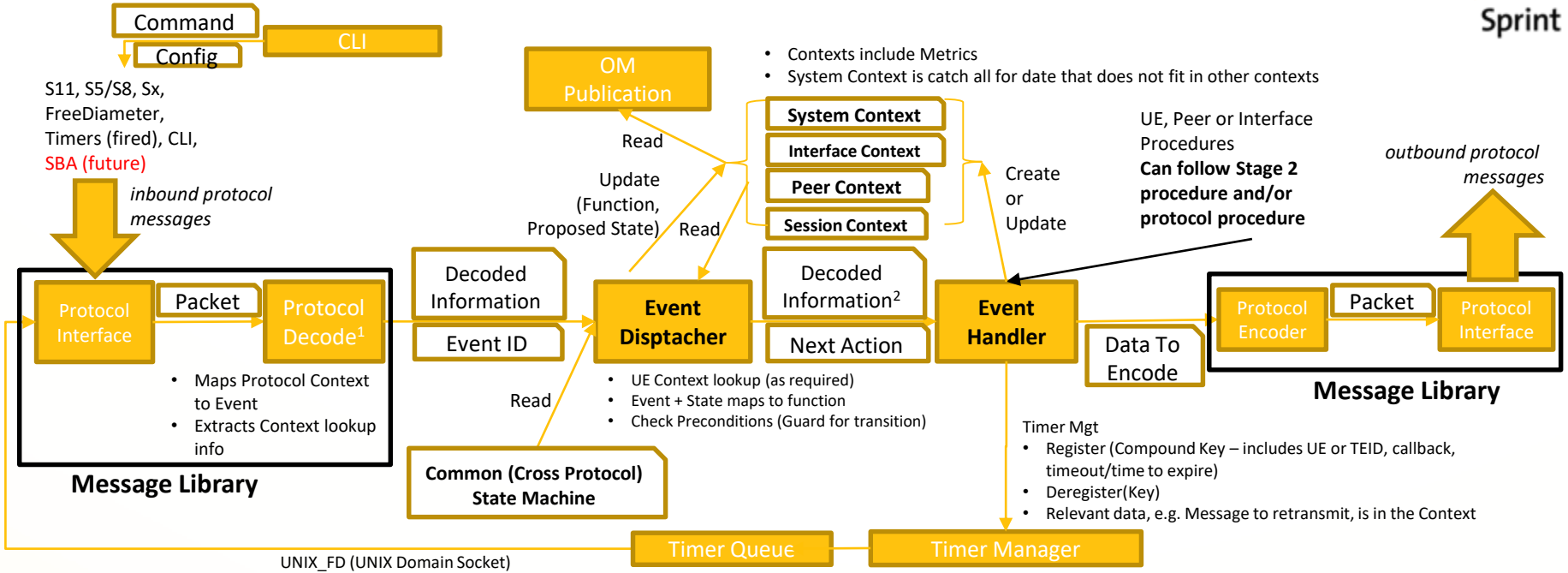
We want OMEC to be as much of a worry free codebase as soon as possible

Submissions will pass basic checks on github then

- Code is brought over to ONF lab, built and deployed
- Tested against commercial, 3rd party tools for functional tests
- Tested against commercial, 3rd party and open source tools for load tests
- Periodic scans by commercial tool for
  - License compliance
  - Code match to other projects (for various violations)
  - Static security scanning

3rd Parties have also performed AI based testing and other methods

Architecture Pattern - Control Plane Functions



LEGEND

Activity

Information

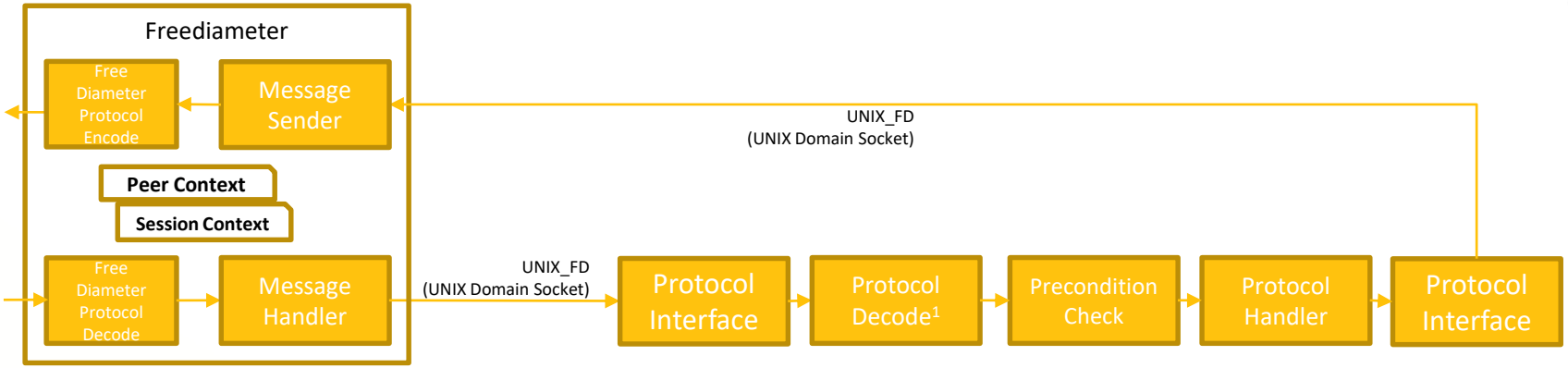
Text in BOLD – Code Stubs that must be customized

NOTES

1 – Decode does NOT occur for FreeDiameter or fired Timers

2 - May not always be present, e.g. retransmission

Architecture Pattern – Existing Stacks



Note: Decode is skipped in CP due to the fact that FreeDiameter has already decoded

Considerations: Would Multiple Diameter Applications ever result in multiple UNIX_FD socket in each direction?

1 – Message is not decoded but the Event is assigned

Cross Message (Request / Answer) checking can take place

Stacks Pattern

Services

Reliability of Message Delivery
Endpoint Path Failure Detection
Piggyback messages
Protocol Errors
Unsupported Versions
Message Invalid Length
Unknown Message
Unexpected Message
Missing Information Element
Invalid Length Information Element
Semantically Incorrect Information Element
Unknown or Unexpected Information Element
Repeated Information Elements
Common Structure Error Handling
Detection of Peer Reset

Items in **bold** can only partially be verified at the Communications Layer.

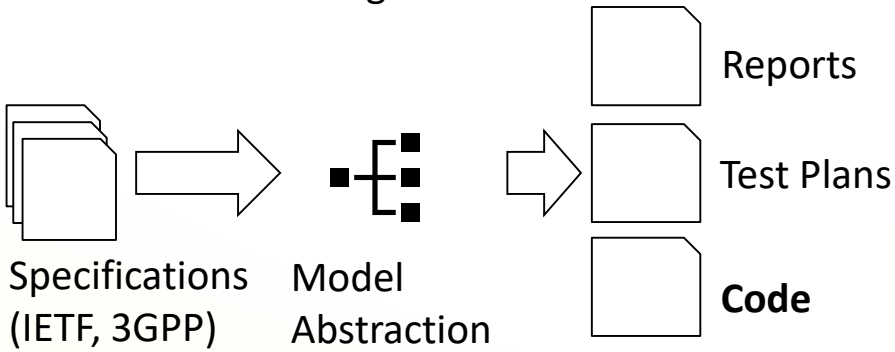
Invalid Length Information Element can be executed in the Communications Layer but will not be able to pinpoint the offending IE.

Common Structure Error Handling is protocol specific.

Automation of Components

Number of customization locations ~ 5

- State Machine
- Control Plane Handler
- Contexts
- Message Handlers (within stacks)
  - Received Messages
  - Sent Messages



Protocol	Code Gen	Test Gen	Spec QA
eGTP	✓	✗	✓
Diameter	✓	✓	✓
S1AP	✓	✗	✗
PFCP	✓	✗	✓
OpenAPI	✗	✗	✗

Example – AVP to dia (AI test format)

From TS 29.212

The Mute-Notification AVP (AVP code 2809) is of type Enumerated ….

The following values are defined:

MUTE_REQUIRED(0)

…

21 ways this is expressed in specifications

6 ways this is expressed in specifications

AVP Flags

dia file entry

Mute-Notification 2089 V M

…

@enum Mute-Notification

MUTE_REQUIRED 0

Example – Message to Code (1/2)

From S6a (TS 29.272)

< Cancel-Location-Request> ::= < Diameter Header: 317, REQ, PXY, 16777251 >
- < Session-Id >
- [DRMP]
- [Vendor-Specific-Application-Id]
- { Auth-Session-State }
- { Origin-Host }
- { Origin-Realm }
- { Destination-Host }
- { Destination-Realm }
- { User-Name }
- *[Supported-Features]
- { Cancellation-Type }
- [CLR-Flags]
- *[AVP]
- *[Proxy-Info]
- *[Route-Record]

Cancel-Location-Request is mapped to CALR
HSS does not receive CALR (it sends it)

CODE - https://raw.githubusercontent.com/omec-project/c3po/master/hss/src/s6as6d_impl.cpp

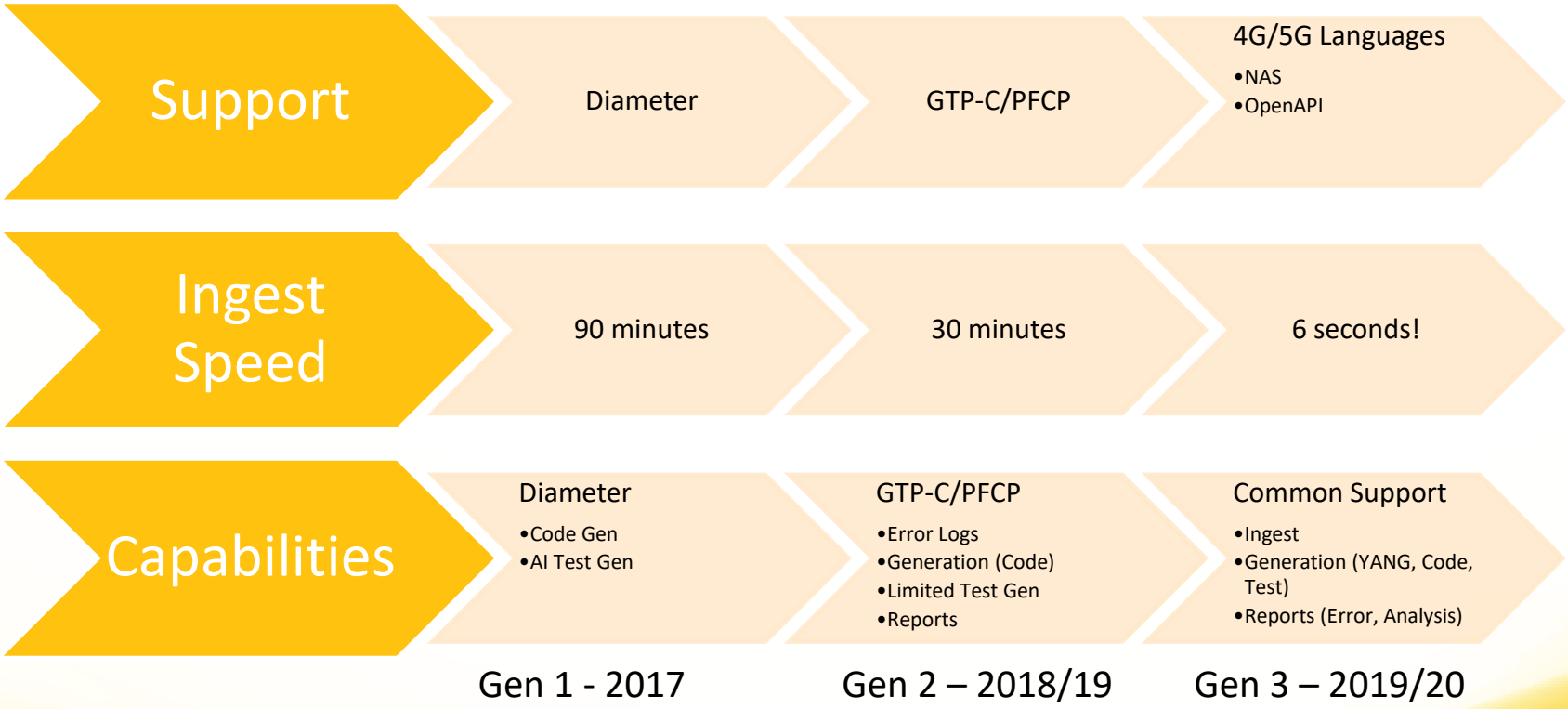
```
// Member functions that customize the individual application
Application::Application( DataAccess &dbobj )
  : ApplicationBase()
  , m_cmd_uplr( *this )
  //, m_cmd_calr( *this )
…
{
  registerHandlers();
}
…
void Application::registerHandlers()
{
  // Remove the comments for any Command this application should
  // listen for (receive).
…
  //registerHandler( m_cmd_calr );
…
}
…
```

Example – Message to Code (2/2)

```
…
// CALR Request (req) Command member functions
// Sends a CALR Request to the corresponding Peer
bool Application::sendCALRreq(FDPeer &peer)
{
  //TODO - This code may be modified based on specific
  //      processing needs to send the CALR Command
  CALRreq *s = createCALRreq( peer );

  try
  {
    if ( s )
    {
      s->send();
    }
  }
  catch ( FDException &ex )
  {
    Logger::s6as6d().error("EXCEPTION - %s", ex.what());
    delete s;
    s = NULL;
  }
  // DO NOT free the newly created CALRreq object!!
    // It will be deleted by the framework after the
    // answer is received and processed.
  return s != NULL;
}

// A factory for CALR reuqests
CALRreq *Application::createCALRreq(FDPeer &peer)
{
  //  creates the CALRreq object
  CALRreq *s = new CALRreq( *this );

  //TODO - Code must be added to correctly
  //      populate the CALR request object

  // return the newly created request object
  return s;
}

// A handler for Answers corresponding to this specific Request
void CALRreq::processAnswer( FDMessageAnswer &ans )
{
// TODO - This code must be implemented IF the application
// receives Answers for this command, i.e. it sends the
// CALR Command
}

// CALR Command (cmd) member function

// Function invoked when a CALR Command is received
int CALRcmd::process( FDMessageRequest *req )
{
// TODO - This code must be implemented IF the application
// receives the CALR command.
  return -1;
}
…
```

CODE - https://raw.githubusercontent.com/omec-project/c3po/master/hss/src/s6as6d_impl.cpp

Progression of Automation

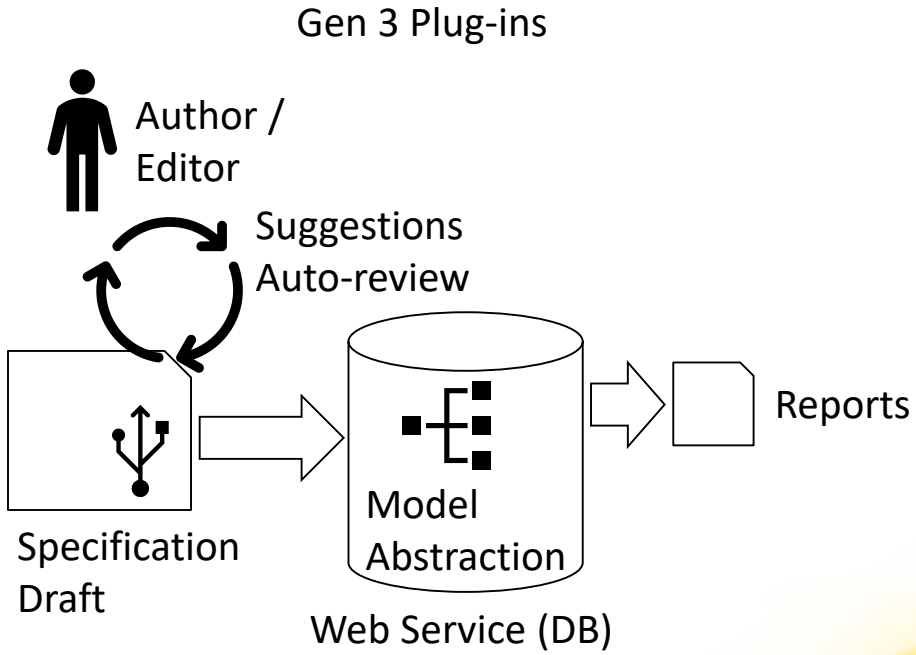


Automation and Quality

Generation 1
- Gen 1 requires **absolute** perfection
- 3700 Errors
- ~900 categories of errors

Generation 2 (2 specs – PFCP and eGTP)
- ~1 dozen CRs & Counting
- 3 workarounds that defy computer science
- Many minor editorial corrections
- System can tolerate some errors

Generation 3
- Combines language support
- Tolerates errors (as much as possible)
- Reports errors
- Centralized Service & Plug-ins



Research

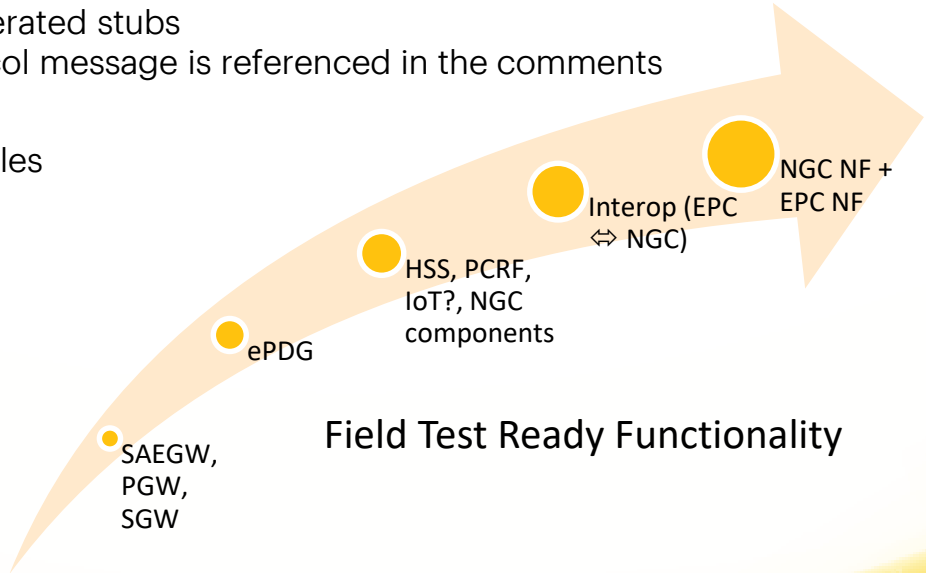
We have begun using techniques such as term substitution, AI trained natural language tools and other techniques with interesting results.

1) Inconsistencies discovered by AI. Three CRs have been created (and accepted) for Stage 2 (sequence diagrams). Including sequence diagrams that reference sequence diagrams.
   - Two were issues present for 10+ years in base LTE spec
   - One was in 23.214 based on referencing.
2) Automated Test Generation with the goal for complete coverage
3) OSS / BSS support

What's Next?

Construction

- TODOs to backlog – answer the question 'where can I help?'
- Gen 3
- Capturing all known references in generated stubs
  - You know *every* location a protocol message is referenced in the comments
- Differential Comment Generation
  - Ability to add to already modified files
- OMEC Design Patterns for
  - User Planes
  - Billing



Sprint

Brighter Future For All