Data Format Description Language

and the

Apache Daffodil Incubator Project

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TRESYS
Deep.

Got Gnarly Data? - Come to BoF Session!

Wednesday 19:00 Terrasse

Use Apache Daffodil (Incubating) to parse your data into XML/JSON

- Bring an example of gnarly data
- We will create a schema for it
- Prize for gnarliest data format

Goal For Today

My goal in this talk is to…

Build Community for Apache Daffodil (Incubating)

- Recruit developers
- Find additional mentors
- Encourage integration of Daffodil into Apache projects that intake/export data

Convince you that….

- DFDL/Daffodil solves an important problem
- Daffodil is technology that would be *fun* to work on

Agenda

Motivation

- The Data Format Problem
- DFDL, standards, Daffodil, and why it is important
- DFDL Schemas

Technology

- DFDL (pronounced “DaFoDiL” or “Dee Eff Dee Ell”)
- Daffodil – the software
  - Code base details and status
  - Cool Stuff Daffodil/DFDL Does for You
    - Streaming unparsing with forward reference
- What’s Next – Plans/Hopes/Dreams

Why is DFDL Needed?

There are *hundreds* of ad-hoc data format description systems

Every Enterprise Software Company

- IBM (10+)
- Oracle(10+)
- SAP(10+)
- Microsoft
- SAS
- SyncSort
- AbInitio
- Pervasive
- Qlik/Expressor

.... Dozens more

Every kind of software that takes in data:

- data directed routing
- database
- data analysis and/or data mining
- data cleansing
- master data management
- application integration

All these data format descriptions are:

- ***proprietary***
- ***ad-hoc***
- ***incompatible***

Even within products of the same company!

Why DFDL is Needed?

Hundreds of data format description systems… means:

- Investment is spread too thin
  - Tools for creating data formats are inadequate
  - No product is comprehensive enough
    - Difficulty is grossly underestimated
  - Some products aren't fast enough
- Customer lock in
- Inflexible packaging
  - Not libraries - must embed some product in your application data flow

Why DFDL is Needed - New Use Cases

Cybersecurity

- Normalization of data
  - Complete rip and rebuild
  - Break down data fully based on DFDL schema
  - Validate at fine granularity
  - Reassemble according to DFDL schema
- Removes a large class of data-borne threats
  - Data adheres to format spec. exactly!
  - Reduces the "attack surface" for software processing it.

Data Publishing

- Open Data mandates

Why DFDL is Needed - New Use Cases

Modernization

- Legacy data systems are still the source, *and target* for much processing
- Coexistence is required for successful incremental modernization

Skills Leverage

- Developers with XML/JSON skills are available
- Legacy data format skills are precious
  - Military data formats - Link16, VMF, USMTF, …
  - COBOL and other FINSERV formats

Solving the Data Format Problem

An Open Standard DFDL

- Multiple implementations that interoperate
  - Commercial & Open Source 
- Long-term sponsors
  - IBM – has their own DFDL implementations
  - US DoD, Canada DND
    - Cybersecurity
- Available DFDL schemas for important data formats

A High-Quality Open Source Library Implementation

- With a supporting community of developers 
- With available commercial support (Tresys)

Data Format Description Language

DFDL: A new open standard

- From the Open Grid Forum (OGF)
- Work began in **2001**, accelerated around 2008
- Major contributors from UK, Canada, and USA
- First Implementation: IBM - November 2011
  - Business-oriented subset of DFDL language
- DFDL Specification - Version 1.0 – Sept. 2014
  - Thick - about 200 pages if you print it.
  - Allows "conforming subsets" - required core is small
- Proposed Recommendation - Status (as of Oct 2016)
  - Waiting for two-implementation interoperability demonstration
- DFDL Workgroup is active
  - Clarifications, Errata on v1.0

Data Format Description Language

DFDL is a way of *describing* data formats

- It is NOT a data format itself!

DFDL combines State-of-the-Art

- Union of capabilities across many marketplace data integration products/tools/packages

DFDL adds small number of real innovations

- Overcome limitations of prior-gen e.g.,
  - Computed Elements Capability
  - Expression language
  - BitOrder

Data Format Description Language

Core Concepts

- Leverage XML Schema (XSDL)
  - Grammar scaffolding
  - Describes the *logical* data model
  - DFDL uses only a *subset* of XML schema
  - Provides standard ways to annotate
- Add annotations
  - Describe the *physical* representation.
- Read and write from same DFDL Schema

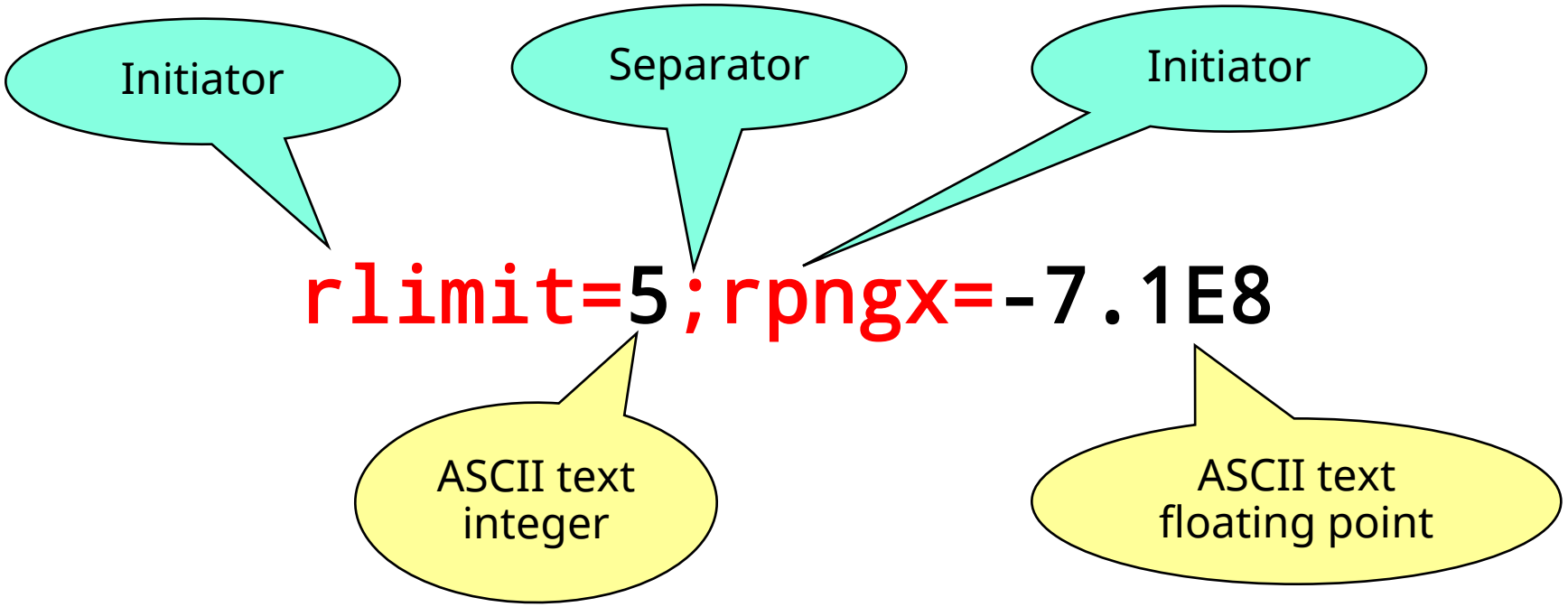
Because Developers [Love | Hate] XML

- The DFDL Schema is based on XSDL
- The Infoset created when parsing data does NOT have to be XML

Example – Delimited Text Data

```
rlimit=5;rpngx=-7.1E8
```

Example – Delimited Text Data



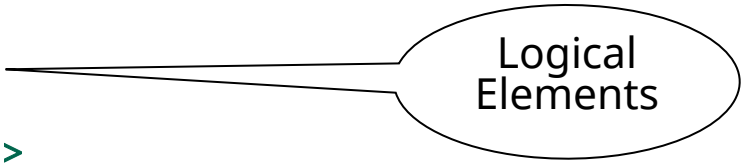
Separators, initiators (aka tags), & terminators are all examples in DFDL of *delimiters*

DFDL Schema

```
<xs:complexType name=“rValues">
  <xs:sequence>
    <xs:element name=“rlim" type="xs:int"/>

     <xs:element name=“rpng" type="xs:float"/>

  </xs:sequence>
</xs:complexType>
```



DFDL schema

```
<xs:annotation>
  <xs:appinfo source="http://www.ogf.org/dfdl/v1.0">
     <dfdl:format representation="text"
             textNumberRep="standard" encoding="ascii"
             lengthKind="delimited“ .../>
   </xs:appinfo>
</xs:annotation>

<xs:complexType name=“rValues">
  <xs:sequence dfdl:separator=";" ... >
    <xs:element name="rLim" type="xs:int"
                dfdl:initiator=“rLimit=" .../>
     <xs:element name=“rpng" type="xs:float"
                dfdl:initiator=“rpngx=" ... />
  </xs:sequence>
</xs:complexType>
```

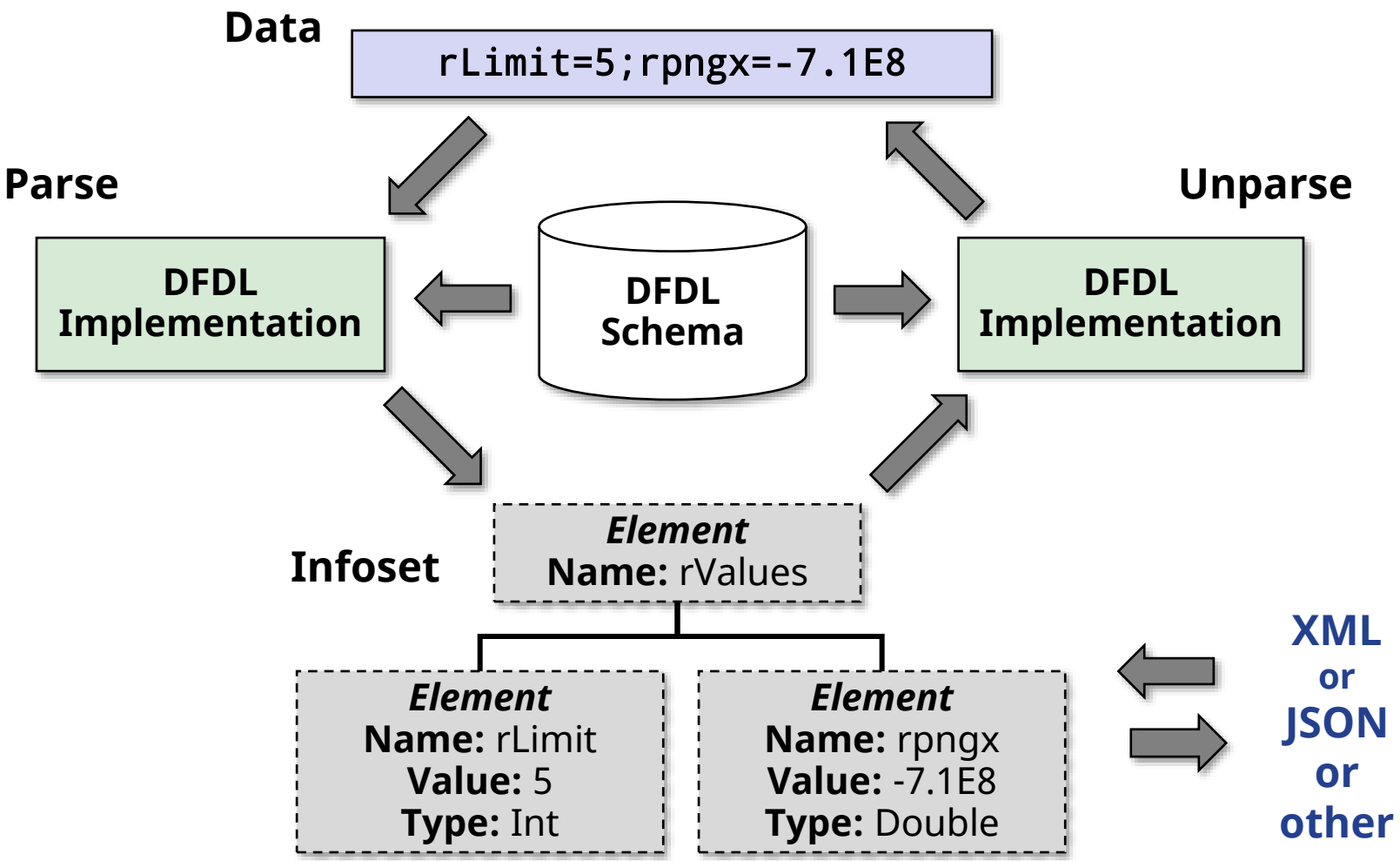
;

rLimit=5

rpngx=-7.1E8

DFDL properties

DFDL Data and Infoset Lifecycle



More DFDL Properties

initiator
terminator
documentFinalTerminatorCanBeMissing
outputNewLine
length
lengthPattern
textStringPadCharacter
textNumberPadCharacter
textCalendarPadCharacter
textBooleanPadCharacter
escapeCharacter
escapeBlockStart
escapeBlockEnd
escapeEscapeCharacter
extraEscapedCharacters
textNumberPattern
textStandardGroupingSeparator
textStandardDecimalSeparator
textStandardExponentRep
textStandardInfinityRep
textStandardNaNRep
textStandardZeroRep
textBooleanTrueRep
textBooleanFalseRep
calendarPattern
calendarLanguage
binaryCalendarEpoch
nilValue
separator
occursStopValue

inputValueCalc
outputValueCalc

textBidi
textBidiTextOrdering
textBidiOrientation
textBidiSymmetric
textBidiTextShaped
textBidiNumeralShapes

byteOrder
bitOrder
encoding
encodingErrorPolicy
utf16Width
ignoreCase

alignment
alignmentUnits
fillByte
leadingSkip
trailingSkip

lengthKind
lengthUnits
prefixIncludesPrefixLength
prefixLengthType

representation

textPadKind
textTrimKind
textOutputMinLength

escapeKind
generateEscapeBlock

textStringJustification
textNumberRep
textNumberJustification

textNumberCheckPolicy
textStandardBase
textNumberRoundingMode
textNumberRounding
textNumberRoundingIncrement
textZonedSignStyle

binaryNumberRep
binaryDecimalVirtualPoint
binaryNumberCheckPolicy
binaryPackedSignCodes
binaryFloatRep

textBooleanJustification

binaryBooleanTrueRep
binaryBooleanFalseRep

textCalendarJustification

calendarPatternKind
calendarCheckPolicy
calendarTimeZone
calendarObserveDST
calendarFirstDayOfWeek
calendarDaysInFirstWeek
calendarCenturyStart
binaryCalendarRep

nilKind
nilValueDelimiterPolicy

useNilForDefault
emptyValueDelimiterPolicy

sequenceKind
hiddenGroupRef

initiatedContent

separatorPosition
separatorPolicy
separatorSuppressionPolicy

choiceLengthKind
choiceLength
choiceDispatchKey
choiceBranchKey

occursCountKind
occursCount

floating
truncateSpecifiedLengthString

decimalSigned

DFDL Schemas

* = in development
** = not yet published

Public (github)	**MIL-STD-2045** **PCAP** **NITF** **PNG** **JPEG** **NACHA** **vCard** **ShapeFile(.shp)**	**EDIFACT** **IBM4690-TLOG** **ISO8583** **BMP** **GIF** **Praat TextGrid** **ARINC429*** **JPEG2000**** **planned: EP, DNG, WMF, EMF, …** **planned: Asterisk, IPFIX**
FOUO (DI2E.net & Forge.mil)	VMF (MIL-STD-6017) USMTF ATO (MIL-STD-6040) **LINK16 (NATO STANAG 5516/MIL-STD-6016)** A-GNOSC REMEDY ARMY DRRS USCG UCOP CEF-R1965 GMTIF (STANAG 4607)	
Commercial License $$$	SWIFT-MT (IBM) HIPAA-5010 (IBM) HL7-2.7 (IBM)	

Other DFDL Implementations

- IBM DFDL - The First DFDL Implementation - v1.0 Nov 2011
  - Embeddable as Library, C and Java
  - Includes Eclipse based tooling - graphical DFDL schema editor/test environment
  - Found in IBM products:
    - IBM App Connect Enterprise product family
    - IBM InfoSphere Master Data Management
    - IBM z/TPF product family
- European Space Agency - DFDL4S = DFDL for Space
  - Embeddable as Library, Java and C++ versions.
  - Binary-data-only subset of DFDL
  - Created by ESA for satellite data descriptions
  - Evolving to be a fully compatible DFDL subset.
  - More info at
    - http://eop-cfi.esa.int/index.php/applications/dfdl4s

Daffodil

The Open Source DFDL Implementation

aka Apache Daffodil (Incubating)

Daffodil - History

- Started out at University of Illinois/NCSA
  - Research project ~2009
  - ❤ Written in **Scala** - runs on Java JVM
- Further developed by Tresys Technology ~2012
  - Funded by the US DoD, Canada DND
  - Open source from the start
  - Version 1.0 – parse only, XML – 2015-03
  - Version 2.0 – parse & unparse, XML + JSON – 2017-09
- Apache Incubator - started 2017-08
  - Version 2.1.0 – 2018-05
  - Version 2.2.0 - available now

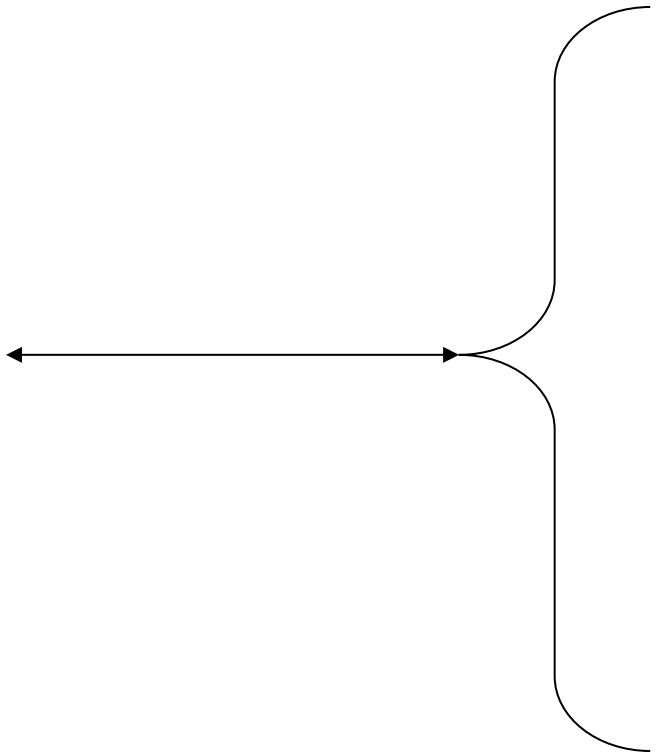
Avoid Version Confusion

DFDL Language Specification

- v1.0

Daffodil Software

- v1.0.0
- v1.1.0
- v2.0.0
- v2.1.0
- v2.2.0
- v3.x
- ....



Daffodil

If you download it, what do you get?

- Jar libraries – runs on JVM
  - Compiler, runtime, utilities, TDML runner
- Command Line Interface
  - Interactive CLI debugger and trace
- Java & Scala API with documentation
- XML and JSON for parse-output, unparse-input

You must get your DFDL schemas somewhere…

- github (DFDLSchemas, others)
- Daffodil/DFDL project on DI2E.net/Forge.mil
- Write them! (and share them!)

Daffodil Internal Components

Compiler
- compiles DFDL schemas to runtime data structures
- Issues diagnostics

Scala API

Command Line Interpreter

Java API

Runtime

DPath - Xpath-like language
- compiler
- runtime

Parser primitives

Infoset
- Convert to/from XML, JSON
- Fast, constant-time access

Unparser primitives

Breakpoint debugger

TDML Runner
- Test (& Tutorial) Data Markup Language

Tests - Unit (Scala)

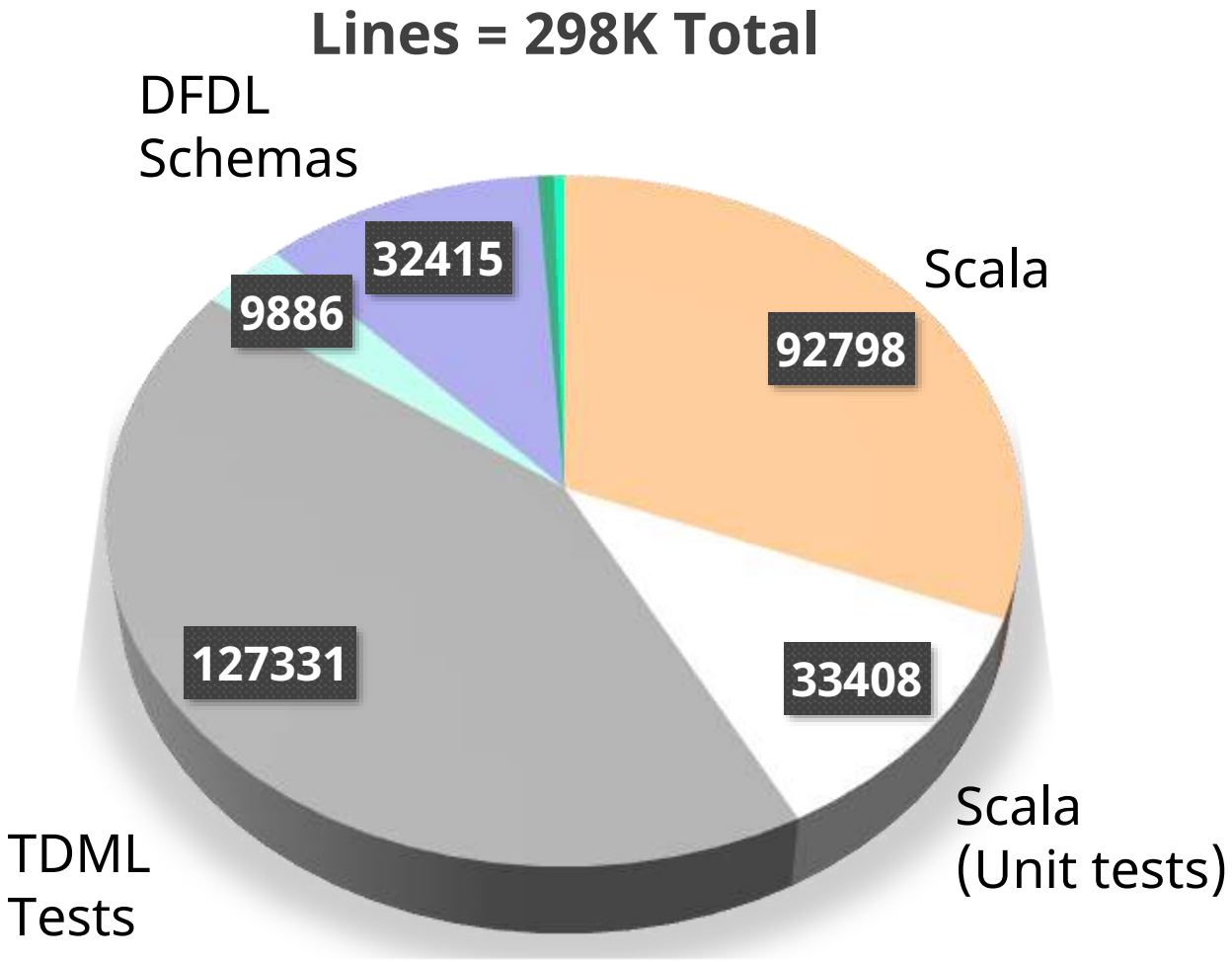
Tests - System (TDML)

Utility Libraries
- for compiler
- for runtime

I/O library
- bits (not bytes), bitOrder
- streaming
- non-8-bit-characters (7, 6, 5)
- unbounded lookahead - parsing/backtracking, and unparsing

Written in Scala

Daffodil Code Base



Data as of 2018-08-06

Daffodil Integrations

- Apache
  - Spark
  - NiFi
  - …Your Project Here…
    - If you can intake/export XML or JSON, then Daffodil enables you to handle anything else describable with DFDL.
- Non-Apache
  - XProc - Calabash XML Pipeline Engine
  - Software^{AG} webMethods^{TM} Integration Server

Some Technical Coolness

Daffodil Runtime Implementation of

Streaming Unparser with Calculated-Value Elements

What is Harder: Parsing or Unparsing?

- Most CompSci people think parsing
  - backtracking - state saving/restoring
  - lookahead (bounded/unbounded)
- Unparsing seems simple in comparison
  - Just a tree-walk of the Infoset outputting each element……

But…

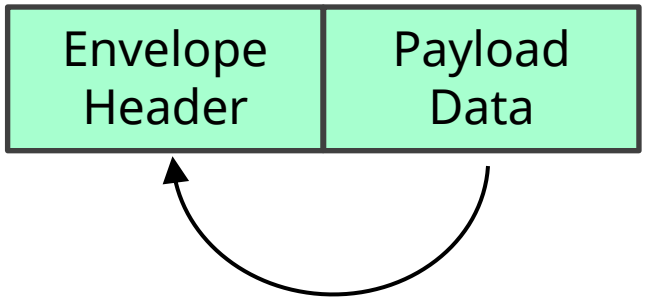
- DFDL has computed elements
  - New innovation over prior-gen format languages
- Let's take a look at what that means for unparsing

Streaming Unparsing

- Limit memory footprint
- Unparser consumes a stream of XML-like events (like SAX - Streaming API for XML)
- The Infoset tree does *NOT* exist
  - We did NOT just parse the data
  - We are starting from the XML events
- Infoset tree is built up as events arrive
  - Can be pruned when tree nodes are no longer needed
  - Infoset stays small even though data stream implies unbounded size

Common: Envelope + Payload

- Data Payload is surrounded by Envelope
- Envelope holds *Stored data length of payload*



Stored Length Limitations on Streaming

```
<Packet>
    <PacketHeader>
      <Seconds>1371631556</Seconds>
      <USeconds>838904</USeconds>
      <InclLen> ??? </InclLen>
      <OrigLen> ??? </OrigLen>
    </PacketHeader>
    <pcap:LinkLayer>
      <pcap:Ethernet>
        <MACDest>005056E01449</MACDest>
        <MACSrc>000C29340BDE</MACSrc>
        <Ethertype>2048</Ethertype>
        ....
      </pcap:Ethernet>
    </pcap:LinkLayer>
  </Packet>
```

Unparse of Envelope needs length of Payload

Payload is a complex object. Must unparse it to determine its length.

Schema with Stored Length

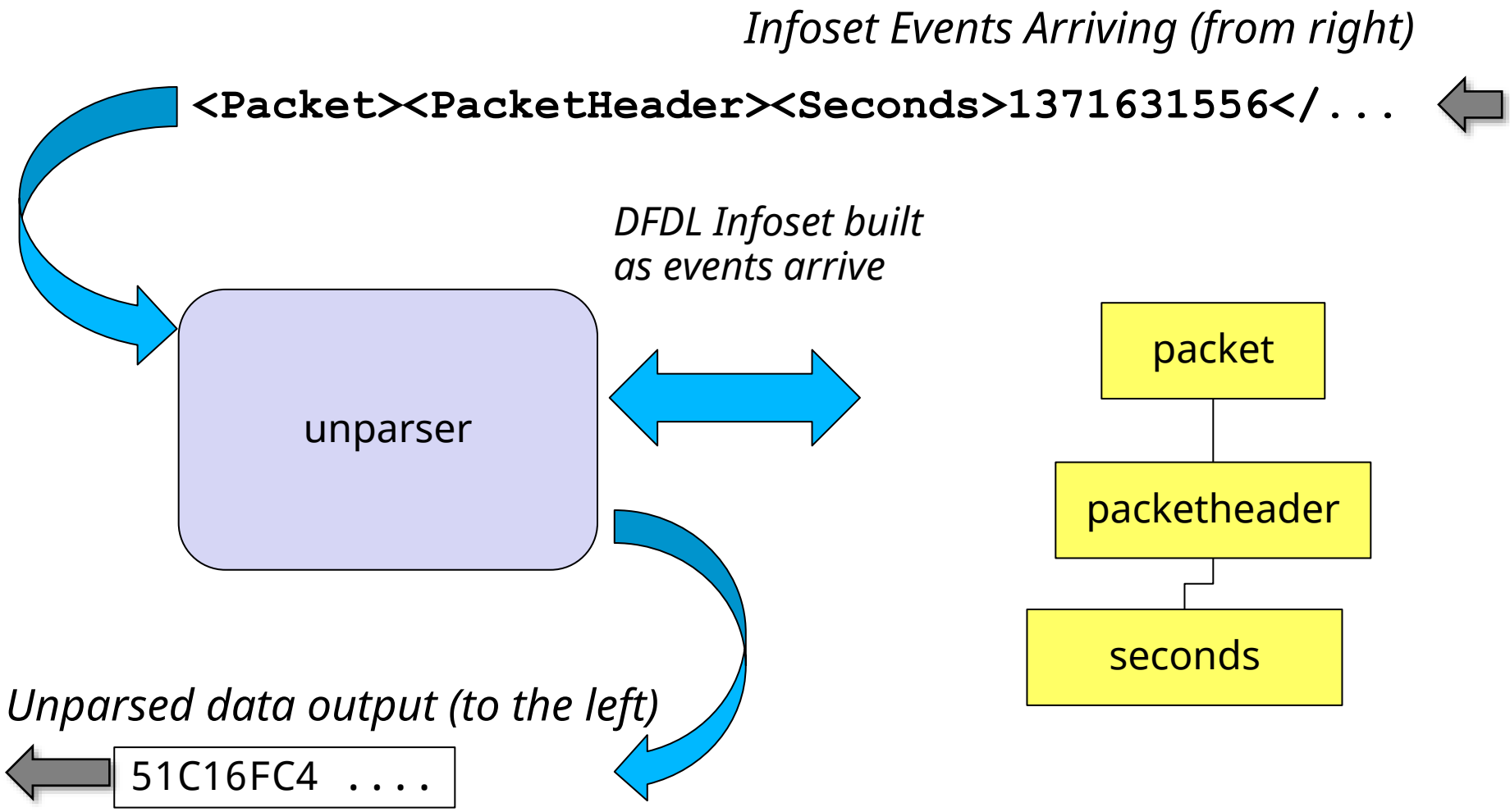
```
<xs:element name="packetHeader">
   <xs:complexType>
      <xs:sequence>
         <xs:element name="Seconds" type="pcap:uint32"/>
         <xs:element name="USeconds" type="pcap:uint32"/>
         <xs:element name="InclLen" type="pcap:uint32"
           ...
         />
      </xs:sequence>
   </xs:complexType>
</xs:element>
...
<xs:element ref="pcap:LinkLayer"
   dfdl:lengthUnits="bytes" dfdl:lengthKind="explicit"
   dfdl:length="{ ../packetHeader/InclLen }"/>
```

Schema with Stored Length

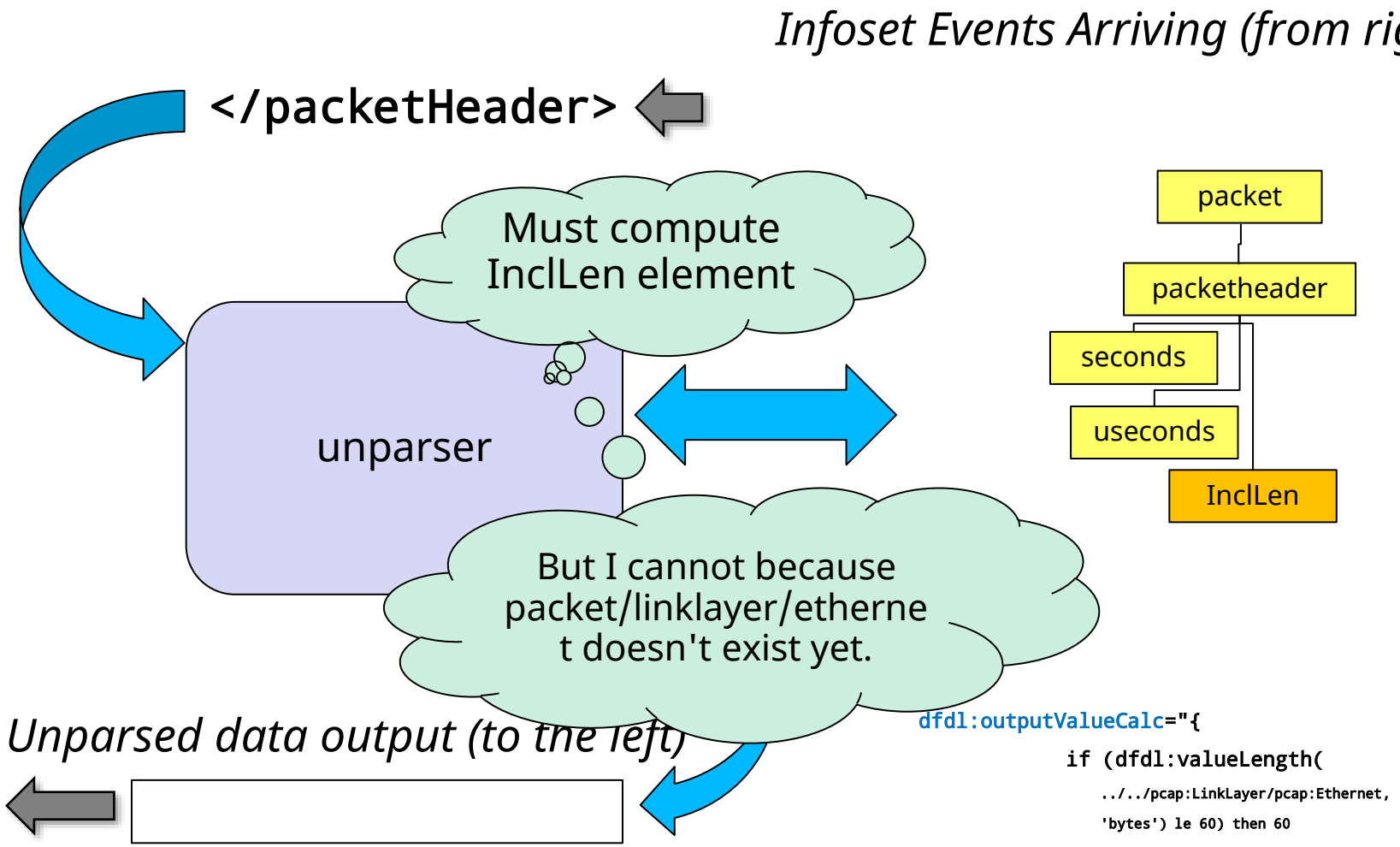
```
<xs:element name="packetHeader">
   <xs:complexType>
      <xs:sequence>
         <xs:element name="Seconds" type="pcap:uint32"/>
         <xs:element name="USeconds" type="pcap:uint32"/>
         <xs:element name="InclLen" type="pcap:uint32"
          dfdl:outputValueCalc="{
           if (dfdl:valueLength(
                    ../../pcap:LinkLayer/pcap:Ethernet,
                    'bytes') le 60) then 60
           else
              dfdl:valueLength(
                    ../../pcap:LinkLayer/pcap:Ethernet,
                    'bytes') }"
         />
         ....
      </xs:sequence>
   </xs:complexType>
</xs:element>
...
<xs:element ref="pcap:LinkLayer"
   dfdl:lengthUnits="bytes" dfdl:lengthKind="explicit"
   dfdl:length="{ ../header/InclLen }"/>
```

Expressions in DFDL's expression language (like XPath)

Streaming Unparsing Illustration



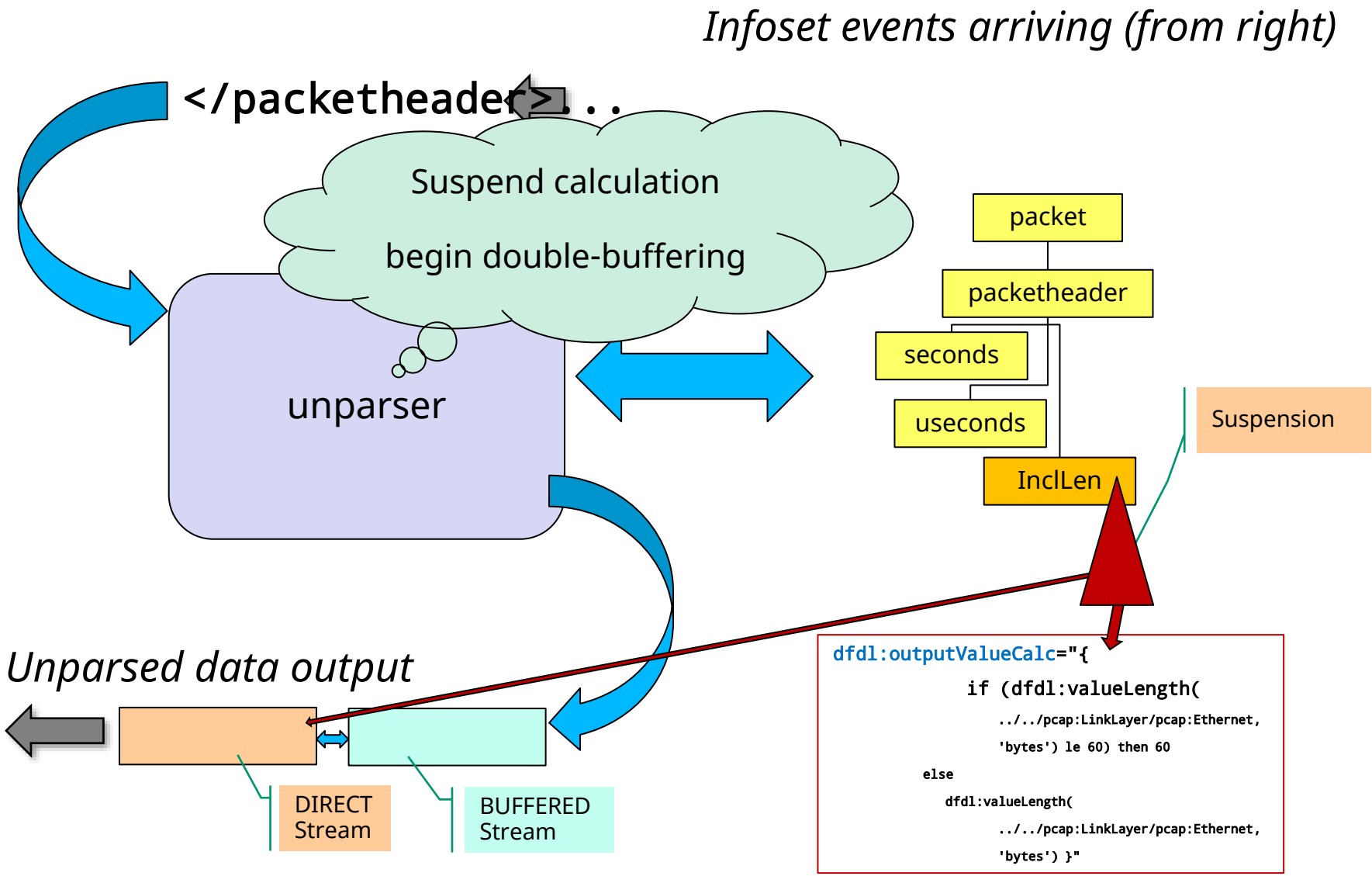
PCAP Streaming Unparsing Illustration



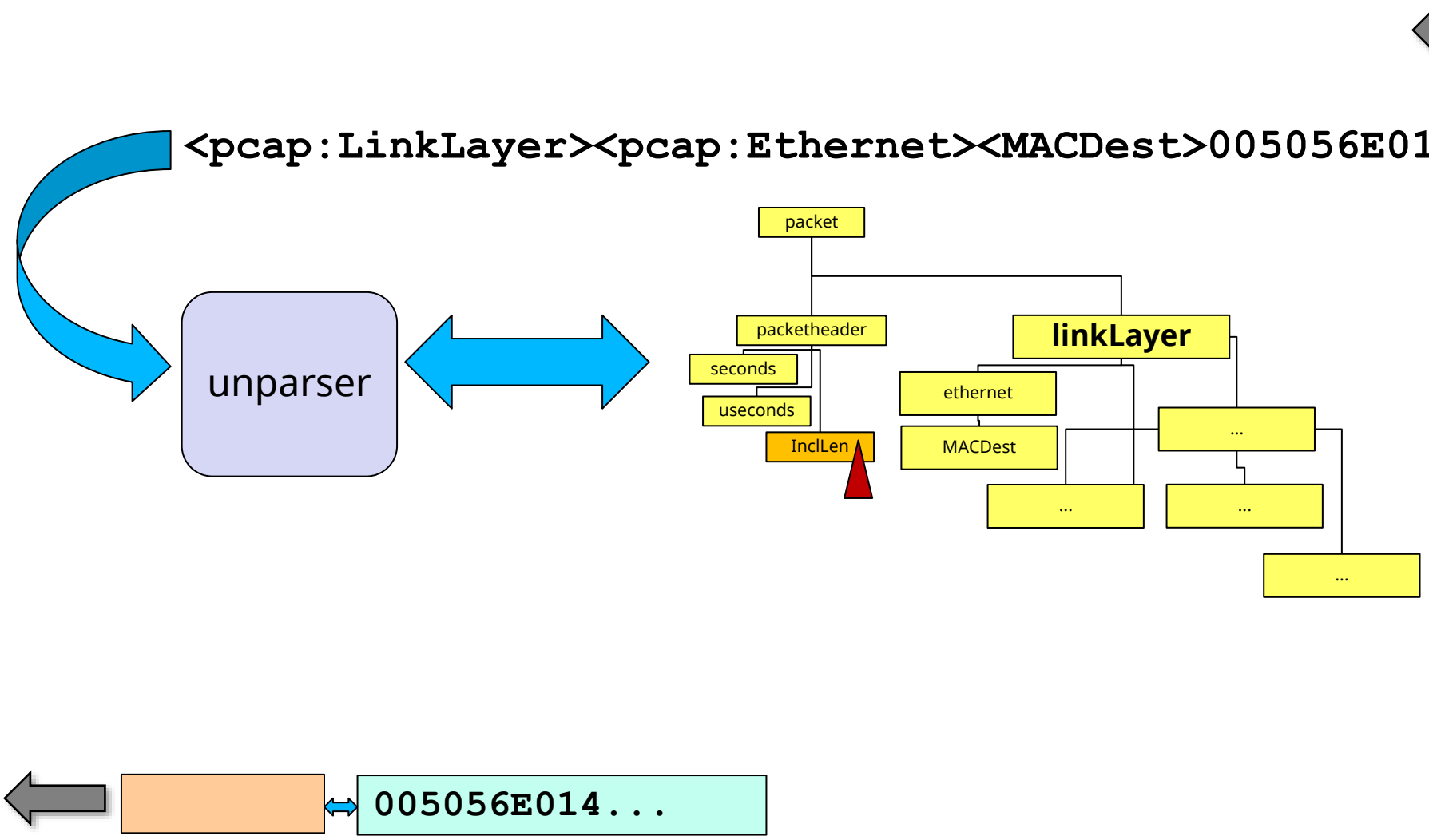
Suspensions and Double Buffering

- Must suspend outputValueCalc computation
  - Suspension object - like a co-routine object
- Blocked until packet/linklayer/ethernet
  - Event arrives
  - Added to Infoset tree
  - All its sub-events/elements arrive and are added
  - And… all of it is unparsed to determine the length of its representation

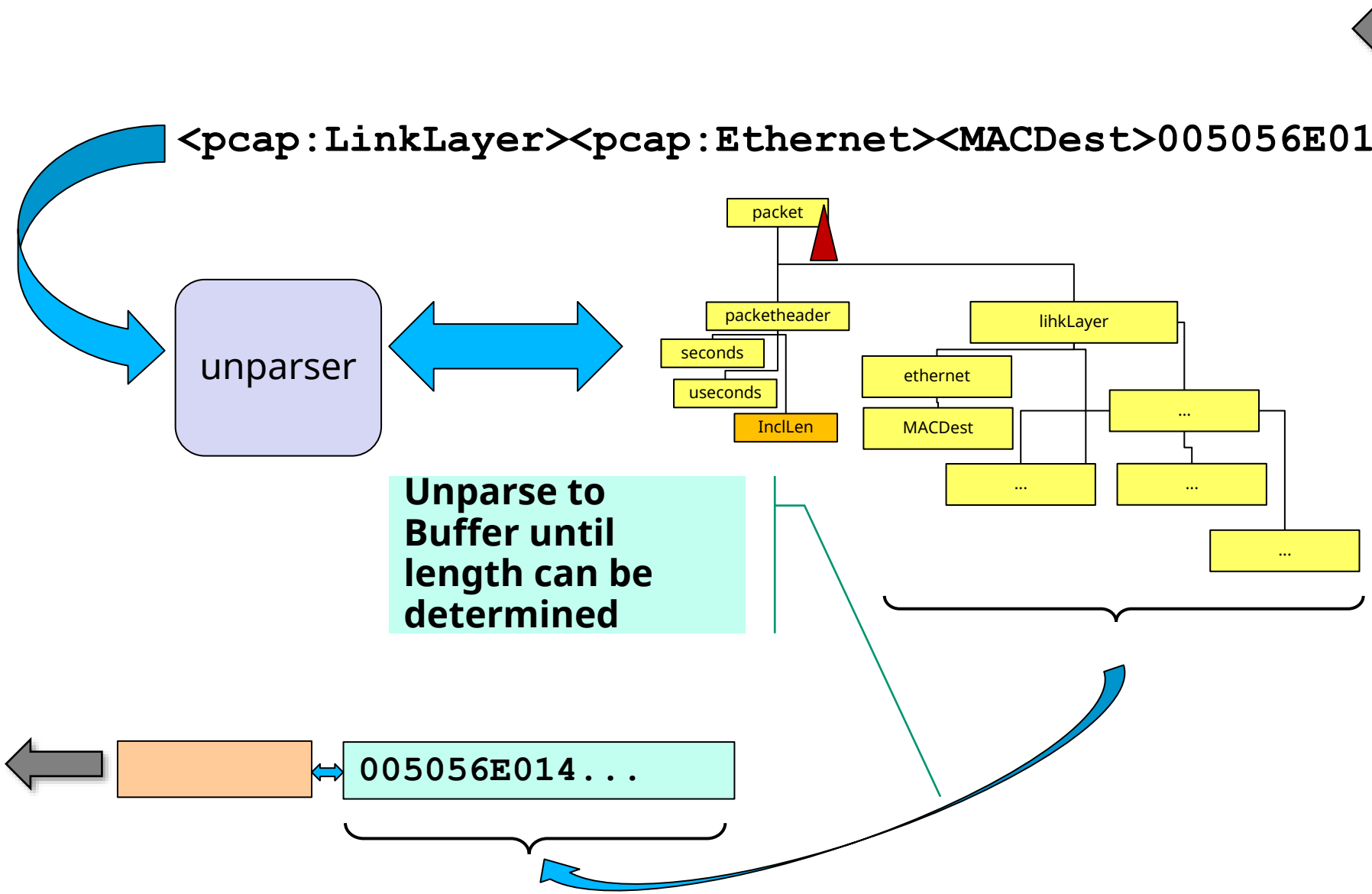
PCAP Streaming Unparsing Illustration



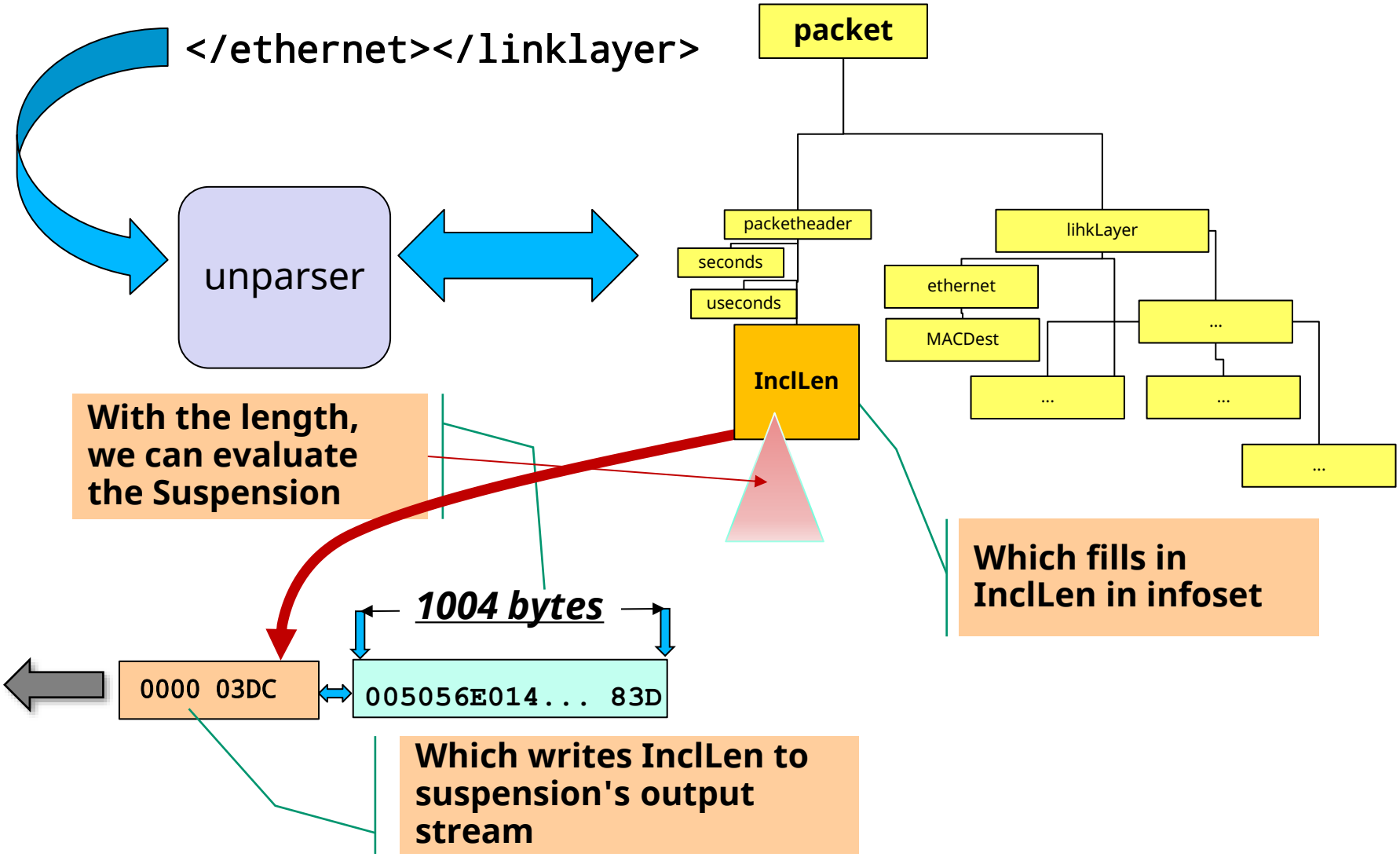
PCAP Streaming Unparsing Illustration



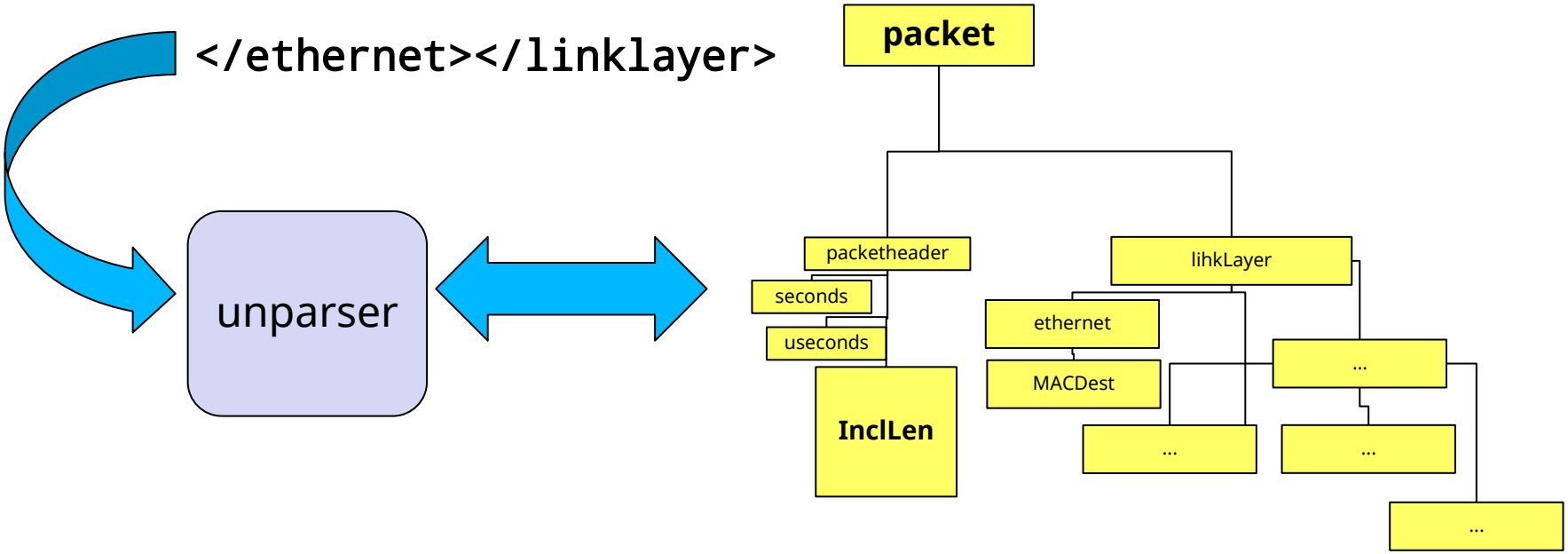
PCAP Streaming Unparsing Illustration



PCAP Streaming Unparsing Illustration



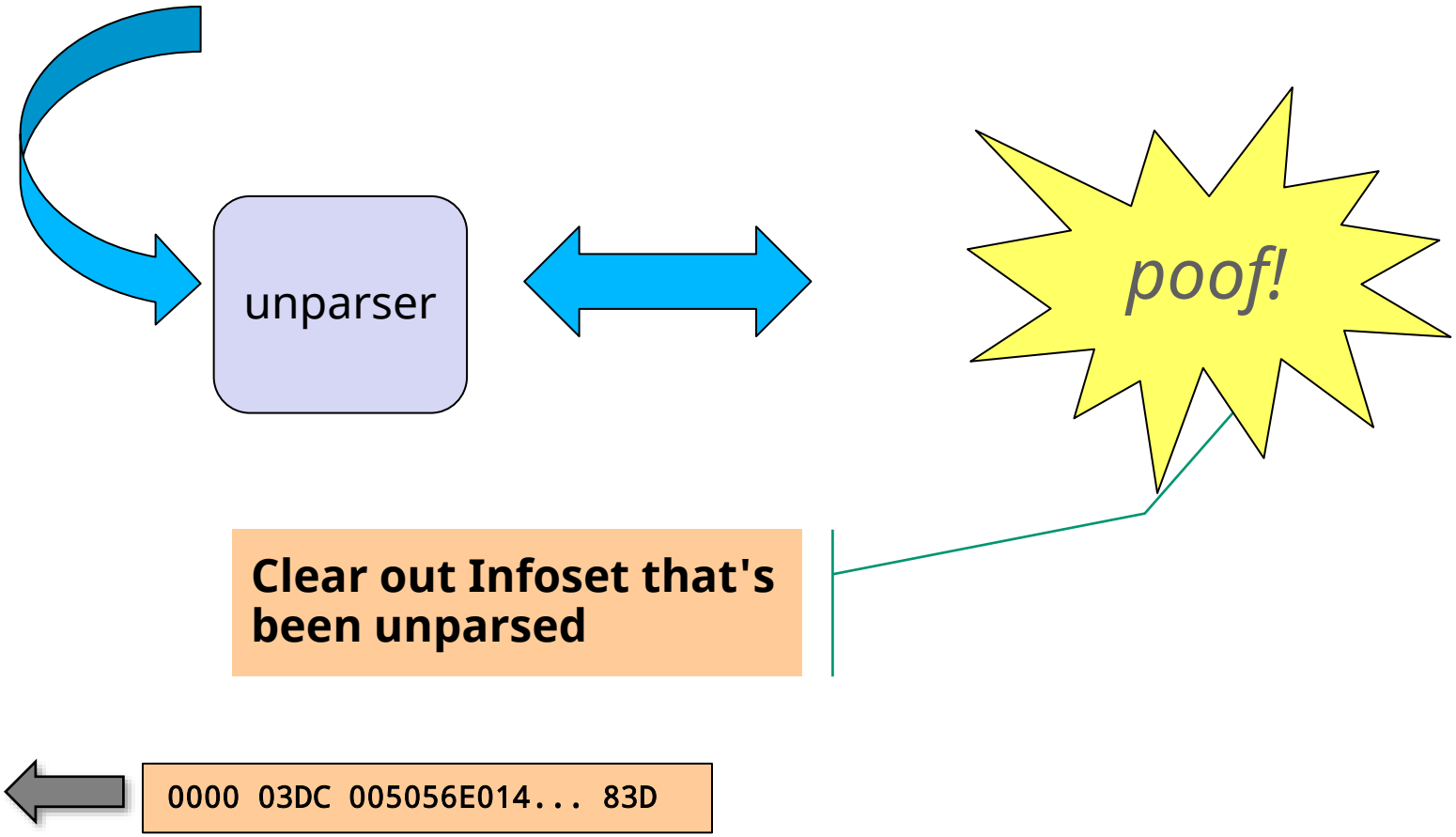
PCAP Streaming Unparsing Illustration



Collapse together buffered and direct streams.

Back to one ordinary stream and low overhead

PCAP Streaming Unparsing Illustration



Streaming Unparsing Illustration

In summary

- Unparsing in DFDL is quite complex
- IMHO: Harder than parsing
- DFDL is much more expressive than other format description languages
  - dfdl:outputValueCalc - computed value elements
- Applications can truly be unaware of stored-lengths - leave that up to Daffodil!

Why is DFDL Needed?

There are *hundreds* of ad-hoc data format description systems

Every Enterprise Software Company

- IBM (10+)
- Oracle(10
- SAP(10+)
- Microsof
- SAS
- Informat
- SyncSort
- AbInitio
- Pervasive
- Qlik/Exp
- Pentaho
- .... Dozens m

Every kind of software that takes in data:

kers)

Software world is very different now.

All this proliferation of redundant engineering can be avoided in the future.

DFDL Language Standard + 300K lines of Apache Licensed Daffodil can eliminate this data format problem ***finally***.

Even within products of the same company!

Collaborators Needed

- Apache Daffodil (Incubating)
  - Growing our Community
    - To graduate from incubator to full Apache project status *requires committers from more organizations*
    - *Scala programmers wanted*
  - Another mentor or two….
- DFDL Schemas
  - Join github DFDLSchemas community

Conclusion

Daffodil and DFDL

- We can finally end the data format problem

DFDL

- Basics
- Innovations: calculated elements
- What it can and cannot do (yet)

Knarly (Gnarly?) Data BoF
Tonight 7pm (19:00)
Terrasse Room

Daffodil 

- Big Scala code base contains - Compiler, Runtime, Test system, many tests
- Runtime - Unparser with calculated elements requires sophisticated co-routine-style behavior

Got Gnarly Data? - Come to BoF Session!

Wednesday 19:00 Terrasse

Use Apache Daffodil (Incubating) to parse your data into XML/JSON

- Bring an example of gnarly data
- We will create a schema for it
- Prize for gnarliest data format

Questions?

Knarly (Gnarly?) Data BoF
Tonight 7pm (19:00)
Terrasse Room

DFDL Specification:

http://ogf.org/dfdl

DFDL Schemas:

https://github.com/DFDLSchemas

Daffodil Open Source:

https://daffodil.apache.org

END

Extra slides may follow for use in optional discussion.

DFDL Doesn't Do...

Limitations, Intended or Otherwise

Things DFDL (v1.0) Does

DFDL is for Data Sets

- Things typically thought of as files full of data about XYZ.
  - Rows, Tables
  - Header-Body-Trailer
  - Hierarchical / Nested record-oriented data
  - Messages
- Industry & Military data interchange formats
  - HL7, HIPAA-5010, SWIFT, NACHA, X25, Link16, etc.

Things DFDL (v1.0) Doesn't Do

- DFDL v1.0 was ***not*** *originally* intended for:
  - Document file formats

    e.g., MS Office documents (.doc), or RTF, PDF
  - Archives like zip files or tar files
  - Core dump/memory image format
  - Storage format of a RDBMS table
  - Graphs of pointers - object graphs dumped from memory

Current DFDL v1.0 Language Limitations

Recursive types

- DFDL v1.0 ***not*** a ***Turing-Complete*** language
- On purpose - it's a feature, not a bug

Position of elements "by offset"

- Random jumping around data
- Ex: TIFF file format
  - TIFF cannot be described in DFDL v1.0

Thanks to
http://langsec.org/occupy/

Why is DFDL Needed?

Q But what about...

- Apache Avro
- Apache Thrift
- Google GPBs
- ASN.1 BER (or PER/DER/XER)

A Those are great, but are *prescriptive*.

They don't describe formats, they *are* data formats themselves.

We need a *descriptive* language.

Things DFDL (v1.0 + *BLOB*) Does

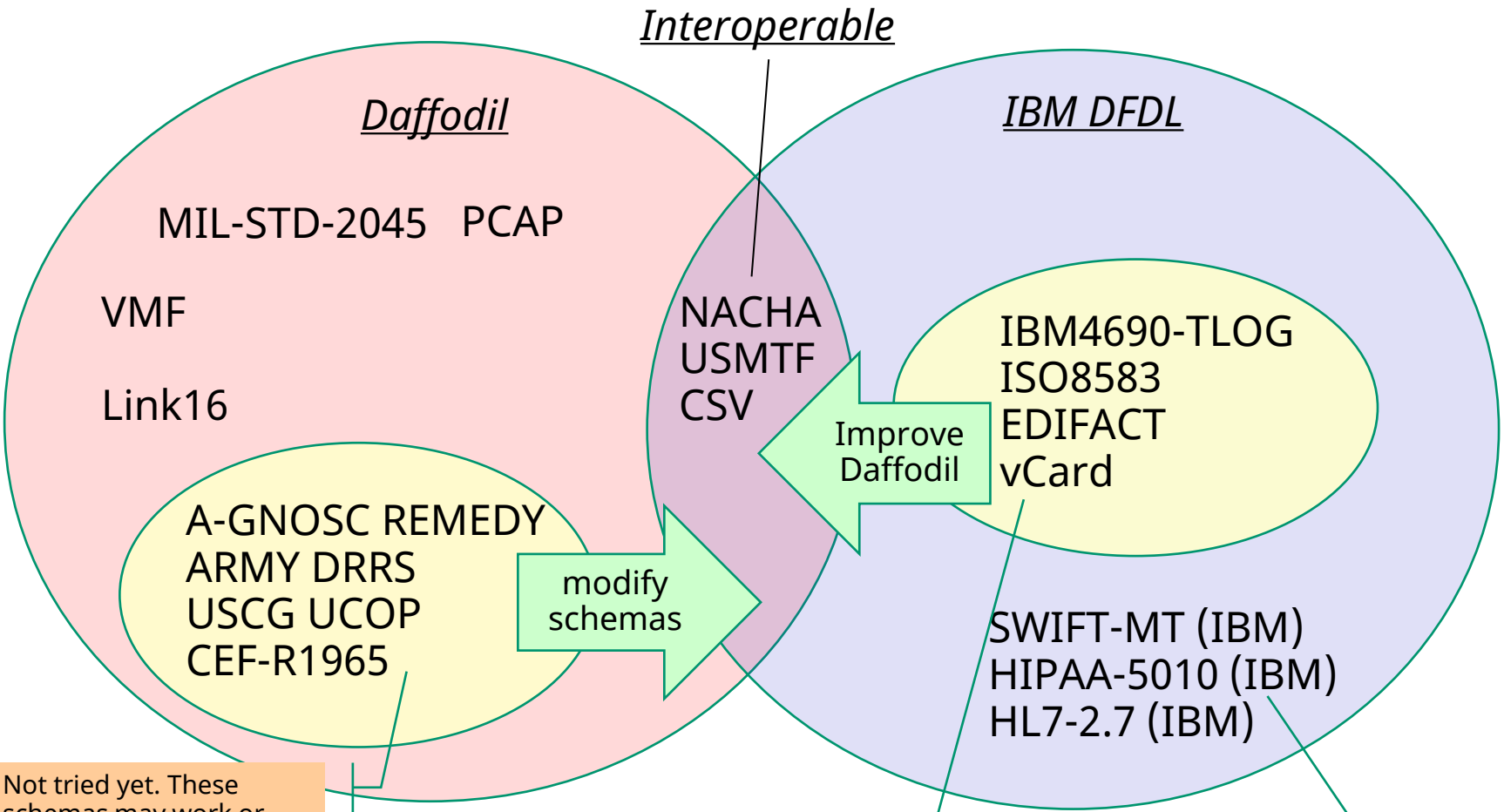
DFDL is for Images and Video

- Originally not in scope
- Large user demand to use DFDL on the metadata content of image file formats
  - Cybersecurity applications
- Adding BLOB (Binary Large Object) feature to DFDL language to enable DFDL to describe image files

Daffodil Future Development

- Cross-validation/test with IBM DFDL
  - Interop test on all IBM-created DFDL schemas
- Tutorials on writing/debugging DFDL schemas
- Improved trace and debug
- Full SAX-style streaming behavior for parsing, unparsing
- Faster schema compilation for large schemas
- Integrate into more frameworks
- Extensions: recursion, BLOB/CLOB, table-lookup,...

Interoperability – Daffodil & IBM



Not tried yet. These schemas may work or require small changes to work on IBM DFDL.

EDI and FINSERVE formats known to require additional DFDL features in Daffodil.

Schemas available under license from IBM; need permission to test.

Why is DFDL Needed? - ASN.1 ECN

What about ASN.1 Encoding Control Notation?

- Already an ISO Standard (since 2008)
- Conceptually similar
  - Logical schema language + notations for physical representation
- Very different in the details.
- Developers [Love | Hate] [ASN.1 | XML]

Differences that matter:

- ASN.1 ECN
  - No open source implementation (as of 2018-08-29)
  - Extension of a binary data standard ASN.1 BER/PER/DER
  - Goal to describe legacy protocol messages
- DFDL
  - Open source Daffodil implementation
  - Extension of a textual data standard XML
  - Goal to be union of data integration tool capabilities for format description