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ElasticFrame

Protocol

IDENTIFYING DATA AND DATA-TYPES OVER TRANSPORT NETWORKS

Source framing / ADTS / NAL / NV12 / Private Data

Some underlying framing
(TCP/UDP/SRT/RIST/RTMP)

The receiver would not be able
to interpret the payload

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THE OLD MEDIA WAY (MPEG-TS)

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Source framing / ADTS / NAL / WHATEVER

Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6

TS-Mux

Some underlying framing

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

TS-Demux

Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6

The receiver do understand

MPEG-TS MULTIPLEX SOLUTION

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- Designed to solve media transport over legacy infrastructure (ASI / ATM) at constant bitrate
- Is designed for simplex solutions
- Do not deal with out of order delivery
- Adds delay and stuffing in CBR mode, is always stuffing all data to 188 bytes frames.
- Has no built-in support for native IP multiplexing.
- High overhead 2% for the top layer (TS packet) then depending on underlying PES frame size ~6% overhead.
- Do not (IP networks) match underlying MTU (TS was designed to match ATM MTU but later in the standardization process ATM changed MTU to 48 bytes)
- Has no reliable sense of loss for IP networks (only 4 bits CC in fragment level)
- Timestamps have only 33 bits and wraps after ~26 hours

BUT THERE ARE SOLUTIONS OUT THERE

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- Most solutions binds to an underlying transport technology
- Some suffers from HOL (head-of-line blocking, for example RTMP)
- Some do not accept a specific media format (JPEG-XS/ H264) to protocol (Any) responsibility
- Most solutions adds unnecessary headers and lowers the payload of what you want to transport
- Some are under licenses that you do not want in your code and some are closed source.

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ElasticFrame

Protocol

ELASTICFRAMEPROTOCOL

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EFP simplifies todays fragmented protocol landscape

EFP is totally agnostic to underlying technology and may be used with TCP and/or UDP based protocols in any mix

ELASTICFRAMEPROTOCOL ALSO ACCEPTS ANY PAYLOAD

Source frames (example H264 NAL)

Source frames (example ADTS)

Source frames (example Private data)

Some underlying framing
(Any with MIN_MTU of 256)

Destination frames (example H264 NAL)

Destination frames (example ADTS)

Destination frames (example Private data)

- Maintains delivery order
  - Also supports out of order
- PTS support
- HOL aging support
- DataType
- Data integrity indication

ELASTICFRAMEPROTOCOL (SEND)

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Super simple API ->

Creation of the source

```
ElasticFrameProtocol myEFPSender(MTU,ElasticFrameMode::sender);
myEFPSender.sendCallback = std::bind(&sendData, std::placeholders::_1);
```

Generating packets of MTU-size to be sent by the underlying transport layer ->

```
void sendData(const std::vector<uint8_t> &subPacket) {
```

When the user instructs the protocol to send data of some sort

```
myEFPSender.packAndSend(myData, ElasticFrameContent::h264, 0, 'ANXB', 2, NO_FLAGS);
```

ELASTICFRAMEPROTOCOL (RECEIVE)

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Super simple API ->

Creation of the receiver (callback + unfinished frames timeout + head of line blocking flush timeout)

```
ElasticFrameProtocol myEFPReciever(0,ElasticFrameMode::receiver);
myEFPReciever.receiveCallback = std::bind(&gotData, std::placeholders::_1);
myEFPReciever.startReceiver(5, 2);
```

Unpack the incoming data->

```
myEFPReceiver.receiveFragment(myData,0);
```

Get the incoming frames

```
void gotData(ElasticFrameProtocol::pFramePtr &frame) {

}
```

ELASTICFRAMEPROTOCOL

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- 64-bit timestamps allow for monotonic time with high accuracy
- Lowest latency possible (Use run to completion mode)
- Supports out of order delivery or managed head-of-line blocking
  - Dynamic out of order delivery to strict Head of line delivery of data.
  - Details later in this presentation
- Low overhead (MTU – 8 bytes payload)
  - Example MTU 1500 == overhead of 0.5%
- (MTU – 8) * 65536 bytes super-frame size
  - Example SRT == 90 Megabytes maximum single frame size.
- Support ‘first come first serve’ with multiple inputs from the same source.
  - One 1+1 mode (See bonding plug-in for all modes supported)
- Can multiplex 256 individual streams (details later in this presentation)

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HOW IT WORKS
HIGH LEVEL

ELASTICFRAMEPROTOCOL

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Source frames (example H264 NAL)

Source frames (example ADTS)

Source frames (example Private data)

Some underlying framing
(Any with MIN_MTU of 256)

Destination frames (example H264 NAL)

Destination frames (example ADTS)

Destination frames (example Private data)

- Maintains delivery order
  - Also supports out of order
- PTS support
- HOL aging support
- DataType
- Data integrity indication

ELASTICFRAMEPROTOCOL FRAGMENTS

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ELASTICFRAMEPROTOCOL FRAGMENTS

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- A super frame consists of:
  - X * type1 fragments if the super frame is larger than MTU - sizeof(type2Frame)
  - And always a type2 frame (single or at the end following x * type1 frames)

```
struct ElasticFrameType1 {
    uint8_t hFrameType = Frametype::type1;
    uint8_t  hStream = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hFragmentNo = 0;
    uint16_t hOfFragmentNo = 0;
};
```

```
struct ElasticFrameType2 {
    uint8_t hFrameType  = Frametype::type2;
    uint8_t  hStream;
    ElasticFrameContent hDataContent = ElasticFrameContent::unknown;
    uint16_t hSizeOfData = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hOfFragmentNo = 0;
    uint16_t hType1PacketSize = 0;
    uint64_t hPts = UINT64_MAX;
    uint32_t hCode = UINT32_MAX;
};
```

ELASTICFRAMEPROTOCOL FRAGMENTS

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There is a corner case where the excess data does not fit the type2 frame
The protocol then ‘tail’ the data in a type3 frame and then terminate the super frame with a type2 declaring the stream content. (The stream concept is detailed later).

```
struct ElasticFrameType1 {
    uint8_t hFrameType = Frametype::type1;
    uint8_t  hStream = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hFragmentNo = 0;
    uint16_t hOfFragmentNo = 0;
};
```

```
struct ElasticFrameType3 {
    uint8_t hFrameType = Frametype::type3;
    uint8_t  hStream = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hType1PacketSize = 0;
    uint16_t hOfFragmentNo = 0;
};
```

```
struct ElasticFrameType2 {
    uint8_t hFrameType  = Frametype::type2;
    uint8_t  hStream;
    ElasticFrameContent hDataContent = ElasticFrameContent::unknown;
    uint16_t hSizeOfData = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hOfFragmentNo = 0;
    uint16_t hType1PacketSize = 0;
    uint64_t hPts = UINT64_MAX;
    uint64_t hDts = UINT64_MAX;
    uint32_t hCode = UINT32_MAX;
};
```

ELASTICFRAMEPROTOCOL SUPERFRAMES

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ELASTICFRAMEPROTOCOL HIERARCHY

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```
struct ElasticFrameType1 {
    uint8_t hFrameType = Frametype::type1;
    uint8_t  hStream = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hFragmentNo = 0;
    uint16_t hOfFragmentNo = 0;
};
```

First byte must be the type number

(130) A value increasing by one for each data block handed over to efp

(25) The current fragment number

(31) Of total fragments for the super frame

Fragment type1

H | Payload

SuperFrame no 130

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

```
struct ElasticFrameType2 {
    uint8_t hFrameType  = Frametype::type2;
    uint8_t  hStream;
    ElasticFrameContent hDataContent = ElasticFrameContent::unknown;
    uint16_t hSizeOfData = 0;
    uint16_t hSuperFrameNo = 0;
    uint16_t hOfFragmentNo = 0;
    uint16_t hType1PacketSize = 0;
    uint64_t hPts = UINT64_MAX;
    uint64_t hDts = UINT64_MAX;
    uint32_t hCode = UINT32_MAX;
};
```

First byte must be the type number

Format is described in next slide

(the number of bytes in the ‘tail’)

(130)

(31)

(the number of bytes used by type1frames)

(Any number but UINT64_MAX)

(Any number but UINT64_MAX)

(Any number but UINT32_MAX)

Fragment type2

H | Payload tail

ELASTICFRAMEPROTOCOL CONTENT DEFINITION

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Different data sources

- Datatypes are defined in the fragments
- If the MSB is set (uint8_t) then
  - ‘Code’ contain a format description
  - Usually a variant. Example, Annex B or AVCC framing of H.264 NAL’s

```
///Payload data types
//Payload data defines ----- START ------
enum ElasticFrameContentDefines : uint8_t {
    unknown,                //Standard                      //code
    privatedata,            //Any user defined format       //USER (not needed)
    adts,                   //Mpeg-4 AAC ADTS framing       //ADTS (not needed)
    mpegts,                 //ITU-T H.222 188byte TS        //TSDT (not needed)
    mpegpes,                //ITU-T H.222 PES packets       //MPES (not needed)
    jpeg2000,               //ITU-T T.800 Annex M           //J2KV (not needed)
    jpeg,                   //ITU-T.81                      //JPEG (not needed)
    jpegxs,                 //ISO/IEC 21122-3               //JPXS (not needed)
    pcmaudio,               //AES-3 framing                 //AES3 (not needed)
    ndi,                    //*TBD*                         //NNDI (not needed)

    //Formats defined below (MSB='1') must also use 'code' to define the data format in the superframe

    didsdid = 0x80,           //FOURCC format                 //(FOURCC) (Must be the fourcc code for the format used)
    sdi,                    //FOURCC format                 //(FOURCC) (Must be the fourcc code for the format used)
    h264,                   //ITU-T H.264                   //ANXB = Annex B framing / AVCC = AVCC framing
    h265                    //ITU-T H.265                   //ANXB = Annex B framing / AVCC = AVCC framing
};
```

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DELIVERY MECHANISM

ELASTICFRAMEPROTOCOL DELIVERY

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Head of line blocking (HOL)

First come first serve

Both modes are supported by the protocol

ELASTICFRAMEPROTOCOL HOL EXAMPLE

OBSERVE!!
Simplified examples to better explain the inner logic!

In this example the super frame (The boat) is of the datatype green and it contains all fragments (The containers) meaning it can anchor and deliver its gods 100% intact.

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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In this example the super frame (The Boat) is of the datatype green, it's missing fragments (The Containers) meaning if it anchors and deliver its goods the receiver will not get all of It's expected payload. In EFP this will trigger the bool 'broken' flag.

HEAD OF LINE EXAMPLES

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ELASTICFRAMEPROTOCOL HOL EXAMPLE

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A perfect day

Boat number
(hSuperFrameNo)

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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Some worse conditions

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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Some worse conditions
Delayed boat number 32 not much but a slight delay

At the receiving end
They will wait for boat 32, when it arrives, they will also unload 32 before unloading boat 33

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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Some worse conditions
Delayed boat number 32 even more

```
ElasticFrameProtocolReceiver( lBucketTimeoutMasterms: 50,  lHolTimeoutMasterms: 20,
```

Number of ms to wait for missing boats

At the receiving end they will wait for boat 32 Before unloading boat 33 and boats with higher numbers. But if boat 32 takes too long time They will just unload the boats that arrived (in order) and ignore boat 32 when or if it arrives..

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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A terrible storm

35

34

31

30

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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This storm was so bad some boats went missing. Some boats came out of order and many boats lost containers

87

33

43

31

48

ELASTICFRAMEPROTOCOL HOL EXAMPLE

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- In the above example 31 will be unloaded.
- Then we wait for boat 32 to arrive but if the timeout triggers we will unload 33
- Then we will wait again for any higher number boats to arrive with all it's containers but if they don't, we unload 43 and 48 and 87.

- If boat 43 would be numbered 32 we would deliver 31. Then wait to see if we could find any missing containers that fell over board. Then after that we would proceed. The missing container search timeout is

```
ElasticFrameProtocolReceiver( IBucketTimeoutMasterms: 50,  IHolTimeoutMasterms: 20,
```

Number of ms cycles to wait for missing containers

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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First come first serve

```
ElasticFrameProtocolReceiver( lBucketTimeoutMasterms: 50,   lHolTimeoutMasterms: 0,
```

Set to 0

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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A perfect day

Exactly as HOL works

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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Some worse conditions

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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Some worse conditions
Delayed boat number 32 not much but a slight delay

At the receiving end
They will unload boats as they arrive
No matter the number.

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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A terrible storm

35

34

31

30

ELASTICFRAMEPROTOCOL FIRST COME. EXAMPLE

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- In the above example. Boat 31, 33 and 87 will be unloaded immediately.
- They will search for the containers for boat 43 and 48. If they find them they will deliver the content from those boats.

- Let’s play with the scenario that we found the containers for boat 43 then we deliver ASAP.. But we did not find 100% of boat 48’s containers . We then unload what we got. But tell the receiver that it’s not everything.
- If containers from boat 48 appear later (after we delivered), we just ignore them.

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PROTOCOL INTERNAL

ELASTICFRAMEPROTOCOL STREAMS

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Data Sources

Introduction to EFP-Streams

ELASTICFRAMEPROTOCOL STREAMS

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Different data sources

The data source can be of the same type
Example.
H264 Annex B for data source 1
H264 Annex B for data source 2
MP4 ADTS for source 3
MP4 ADTS for source 4
MP4 ADTS for source 5

Each data source gets mapped to a stream

EFP has a stream-pool
of 255 streams

(can be extended if
needed in the future)

ELASTICFRAMEPROTOCOL STREAMS

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Streams are stateless and can be replaced by another data sources. Of same type or different data type.

Can be used by external 1+1 mechanisms switching data from different sources

ELASTICFRAMEPROTOCOL STREAMS

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Streams makes it possible to send multiple services of the same type using the same underlying socket

EFP provides:

- Stream number
- StreamType + Code (together defining the payload)
- PTS / DTS

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WORKING WITH PRIVATE DATA

ELASTICFRAMEPROTOCOL PRIVATE DATA

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4 Different ways of embedding private data

- *A stream*
  - Is a contiguous flow of data just as for example a video stream or audio stream
  - May be used for streaming content not defined by the protocol
- *Embedded data*
  - Embedded inside the actual payload of a stream
  - May be used to embed smaller payloads associated with that particular frame of data.
- *Type 0*
  - A packet inserted at any timepoint in the stream of network packets
  - May be used for inserting time critical data anywhere in the stream of all other multiplexed data.
  - A use case could be insertion of markers or time transfer protocols.
- *Opportunistic data transport*
  - Data filling packets up to MTU where the streams do not.
  - May be used for sending non time critical background data where there is no need to meet a timed delivery of the content.

All methods above may be combined.

ELASTICFRAMEPROTOCOL STREAM

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A stream can be of a known defined standard
Or user defined

ELASTICFRAMEPROTOCOL EMBEDDED DATA

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- Private data can also be inserted at the beginning of a super frame
  - In the embedded data segment (explained later)

- That private data can more easily be associated with that particular payload data since the callback containing the data also contains the private data.

- Using the EMBEDDED_PAYLOAD flag indicates there is embedded data

ELASTICFRAMEPROTOCOL EMBEDDED DATA

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- Embedded data can be maximum 65535 bytes

```
struct ElasticEmbeddedHeader {
    uint8_t embeddedFrameType = ElasticFrameEmbeddedContentDefines::illegal;
    uint16_t size = 0;
};
```

```
enum ElasticFrameEmbeddedContentDefines : uint8_t {
    illegal,                //may not be used
    embeddedPrivateData,    //private data
    h222PMT,                //pmt from h222 pids should be truncated to uint8_t leaving the LSB bits only then map to streams
    mp4FragBox,             //All boxes from a mp4 fragment excluding the payload
    lastEmbeddedContent = 0x80
    //defines below here do not allow following embedded data.
};
```

ELASTICFRAMEPROTOCOL EMBEDDED DATA

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- Multiple embedded data segments can be concatenated. The last embedded content bit defines no further embedded content.

```
lastEmbeddedContent = 0x80
```

ELASTICFRAMEPROTOCOL TYPE 0 FRAMES

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- Any fragment in the stream can also contain a Type 0 fragment. Type 0 may contain private data, the size of MTU-1.
- A type0 can be inserted wherever. Before the first fragment or after the last or anywhere in between. Any number of type0 in a row can also be inserted.
- There is no sense of data integrity or counters for type0 frames. That has to be provided by a higher-level protocol.

ELASTICFRAMEPROTOCOL OPPORTUNISTIC DATA TRANSPORT

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- Opportunistic data is using the possible extra space (to MTU) in type2 and Type 3 frames
- Opportunistic data provides no guarantees at all when it comes to bps

ELASTICFRAMEPROTOCOL OPPORTUNISTIC DATA TRANSPORT

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Opportunistic data is interleaved across all streams.

Opportunistic data is interleaved across stream to better utilize the tail MTU mismatch of all possible fragments.

The benefit of doing that is better utilization and higher transfer rates.

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CHECK IT OUT AT :

https://github.com/agilecontent/efp

WHATS NEXT

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- Tests. Tests. Tests. And more Tests. We can never test too much.
- API documentation.
- More examples.
- Implement opportunistic data.

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ElasticFrame

Protocol

THANKS FOR ATTENDING