PPETP: Peer-to-Peer Epi-Transport Protocol

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Outline

1. Motivation (why I am here)
2. PPETP overview
   - Data reduction
   - Network structure
   - PPETP and other protocols (SDP/RTSP/. . .)
   - Plugin structure
3. Conclusions

Motivation
What is?

PPETP:

- The **initial motivation** was
  - P2P streaming multimedia data (e.g., video)
  - to nodes with limited upload bandwidth (e.g., residential users)
- It **evolved** in a overlay multicast P2P protocol
  - limited upload bandwidth nodes can contribute
  - Builtin **resiliance** to peer departure/packet loss/poisoning
  - **Integrable** with existing protocols
  - Potentially useful tool

Motivation (2)
Current status

Do you have **running code***?* **Yes***, we have*

- Implemented in an Ada library (+ side software)
- Source code available on *SourceForge*
- **Stable** core, but fine details still “fluid”
- Current version documented in an I-D

Right time to get some feedback

PPETP Overview

PPETP Characteristics

- Reduction procedure
- Network structure
- Pseudo-address (and integration with other protocols)
- Plugin structure

PPETP Overview

Reduction functions

Initial Design Goals
(Historical)

- We wanted a protocol that could cope with

Asymmetric bandwidth

- Residential users have not enough bandwidth to upload live multimedia content

Data losses

- Data losses due to
  - Congestion
  - Sudden peer departure

The cornerstone: the reduction procedure

- The idea of reduction:
  - The data stream is a sequence of packets
  - We reduce the size of each packet (by a factor of R)
  - The node will upload the reduced packets
  - Each node will...
    - **Receive** $N \geq R$ reduced packets from other peers
    - **Reconstruct** the content packet
    - **Reduce** the content packet and **send** the result to other peers

Example of reduction function

Inspired to secret sharing techniques (DCC'08)

1. A **content packet** is interpreted as a matrix

$$\mathbf{C} = \begin{bmatrix} c_1 & c_{R+1} & \cdots \\ c_2 & c_{R+2} & \cdots \\ \vdots & \vdots & \\ c_R & c_{2R} & \cdots \end{bmatrix}$$

   with R rows and elements in GF(2^d)

2. **At startup** each node chooses the **reduction parameter** $b \in$ GF(2^d) and creates the row vector

$$\mathbf{r}_b = [1, b, \cdots, b^{R-1}]$$

3. The **reduced packet** is the packet corresponding to the row vector

$$\mathbf{u}_b = \mathbf{r}_b \mathbf{C}$$

   Note: $\mathbf{u}_b$ is R times **smaller** than $\mathbf{C}$

Example of reduction function

Packet reconstruction

1. A node receives $\mathbf{u}_1, \ldots, \mathbf{u}_R$ reduced versions corresponding to reduction parameters $b_1, \ldots, b_R$

2. The node reconstructs $\mathbf{C}$ by solving

$$\underbrace{\begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \vdots \\ \mathbf{u}_R \end{bmatrix}}_{\mathbf{U}} = \underbrace{\begin{bmatrix} \mathbf{r}_1 \\ \mathbf{r}_2 \\ \vdots \\ \mathbf{r}_R \end{bmatrix}}_{\mathbf{R}} \mathbf{C} = \underbrace{\begin{bmatrix} 1 & b_1 & b_1^2 & \cdots & b_1^{R-1} \\ 1 & b_2 & b_2^2 & \cdots & b_2^{R-1} \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & b_R & b_R^2 & \cdots & b_R^{R-1} \end{bmatrix}}_{\mathbf{R}} \mathbf{C}$$

- Matrix $\mathbf{R}$ invertible iff $b_i \neq b_j$
- Values b_i communicated during handshaking $\Rightarrow$ matrix $\mathbf{R}$ inverted only once

Reduction functions in PPETP

- **Generalization** of the just described approach
- PPETP does *not* **fix** a specific reduction procedure, but
  - Reduction procedures are expected to be defined in external documents (**plugin structure**, easier to extend)
  - Current I-D includes two *prêt-à-porter* reduction procedures
    - **Vandermonde** (described above)
    - **Basic** (no reduction at all)
- PPETP reduction functions are **expected to**
  - **Reduce** packet size
  - Be **parametrized**
  - Enjoy the R-**reconstruction property**

Reduction functions in PPETP

Why they help

- **Smaller bandwidth** required for reduced packets
  (*puncturing* options also available)
- Resilience to **packet loss**
  - **Receive** data from $N > R$ peers
  - **Reconstructs** as soon as R out of N reduced packets are received
  - Streaming can continue even if up to $N - R$ peers suddenly leave
- Counteract **poisoning**
  - **Receive** data from $N > R$ peers
  - **Reconstructs** using R reduced packets
  - **Check coherence** of the remaining $N - R$ packets

Data format

- Content packets are just "a bunch of byte"
- Any type of packet (RTP, RTCP, . . .)
- Any data type (video, audio, 3D?, smells?)
- Encoded as you want (classical, scalable, multiple description, distributed, . . .)

PPETP Overview

Network structure

Network structure in PPETP

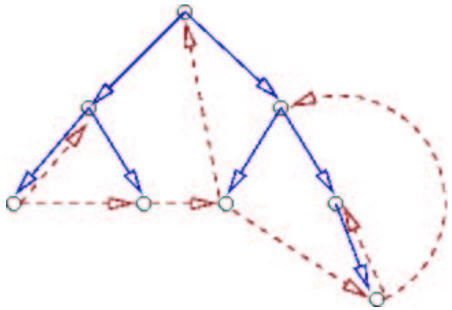
- **Stable** network (*push*)
  - Peers **open/close connections** using **control packets**
  - Control packets
    - ⇒ can be sent under the **control** of the **application**
    - ⇒ can be sent **on the behalf** of another node (if security policies allow)
    - ⇒ can trigger **connection establishment procedure**
  - **Connection parameters** (e.g., reduction parameters) are communicated during the handshaking

- No specific network topology (**separation** between topology and transport)

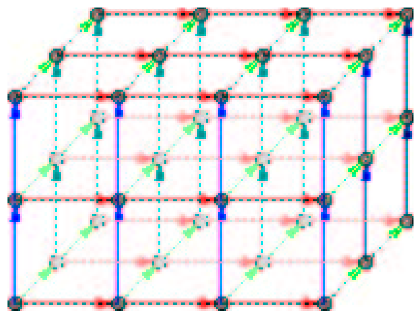
- Runs over **UDP** (IPv4/IPv6) (DCCP?)

Network structure in PPETP (2)

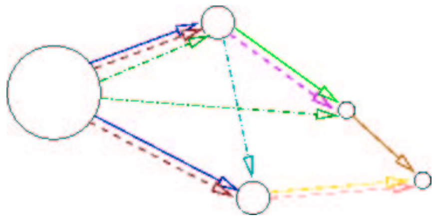
Only constraint: at least R upper peers



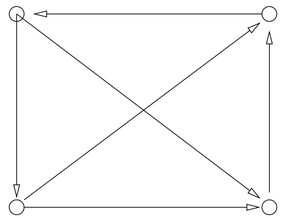
Multiple trees



Onion skin



Heterogeneous network
(size = upload bandwidth)



Non-acyclic network

Network creation

Centralized or distributed? You choose. . .

- Strongly centralized
  - A central server sends `Start` packets on the behalf of the new peer
  - Server load
  - Good control on the network
- Strongly distributed
  - The new node receives “entry point” of a DHT and finds its own peers
  - Small server load
  - Less control on the network structure
- Something in between. . .

PPETP Overview

Pseudo-address

Pseudo-address of a PPETP session

- It would be convenient to refer to a PPETP session with an **(host, port) pair**
- A PPETP session is a **distributed** object

? What kind of a meaning can we associate to a (host, port) pair?

Pseudo-address of a PPETP session (2)

- A PPETP session is a complex object that needs to be **configured** (e.g., by fixing the reduction procedure)
- In a PPETP pseudo-address (host, port)
  - **host** is the address of an host queried for configuration parameters
  - **port** is a 16-bit integer that identifies the PPETP session
  - Every P2P structure needs a **starting point**, for PPETP the starting point is the configuration server
- Configuration query protocol
  - Light-weight and stateless
  - Designed to be as DoS-resilient as possible
  - It allows for user authentication
  - It can redirect the user to more complex protocols (handled by plugins)

Pseudo-address and existing protocols

The availability of a pseudo-address makes it easy to integrate PPETP with existing protocols

```
v=0
o=
s=PPETP example
c=IN IP4 ppetp.example.com
              :
              :
  other SDP lines
              :
              :
m=video 42000 RTP/AVP/ PPETP 0
```

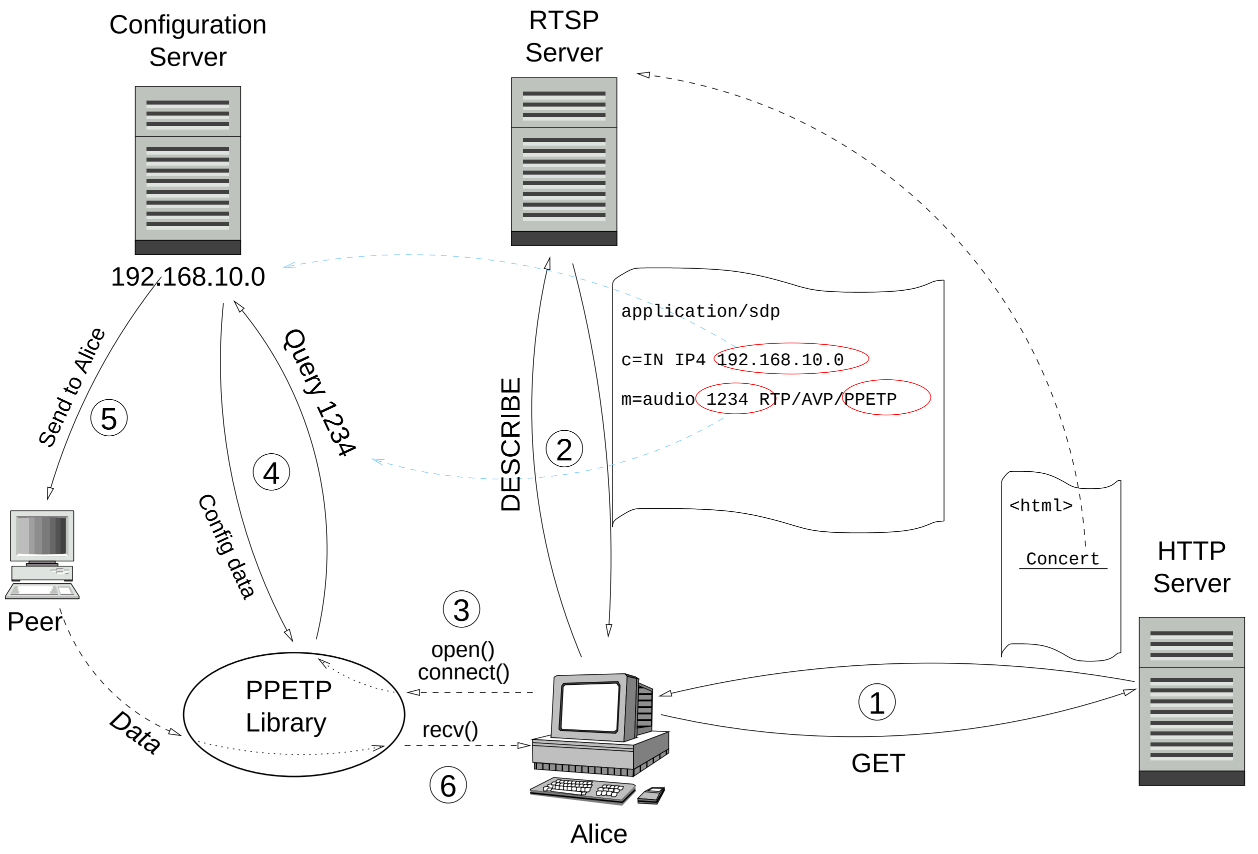
Configuration host

PPETP session number for RTP RTCP packet are sent over session number 42001

Streaming is done over PPETP

The standpoint of the application writer

To the application programmer PPETP looks like a **multicast** transport protocol.



PPETP Overview

Plugin structure

Plugin structure in PPETP

- PPETP makes use of several *tools* (e.g., reduction procedures, signature algorithms, connection establishment procedures)
- PPETP does not **fix** them, but demands their definition to external documents
- For the sake of usability the I-D includes definition of **default versions** of the tools
- **Data format** designed for easy extendability
  - Data processed by plugins are defined as **opaque** sequence of octets
  - It is possible to load new plugins at **run-time**

Plugin structure in PPETP (2)

Example: data packet format

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=0|C|P|I|F|G|H|Channel|       Reserved        |  PPETP Magic  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Stream ID        |           Sequence Number             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:                    Payload (variable size)                    : <- Depends on
:                                                               :    reduction function
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:              Sender Signature (variable size)                 : <- Depends on
:                                                               :    signature algorithm
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Plugin structure in PPETP (3)

After signature verification

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=0|C|P|I|F|G|H|Channel|       Reserved        |  PPETP Magic  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Stream ID        |           Sequence Number             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:                    Payload (variable size)                    :
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:              Sender Signature (variable size)                 :
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Plugin structure in PPETP (4)

After header processing

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=0|C|P|I|F|G|H|Channel|       Reserved        |  PPETP Magic  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Stream ID        |            Sequence Number            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :    Handed to
:                    Payload (variable size)                    : <- reconstruction
:                                                               :    plugin
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
:              Sender Signature (variable size)                 :
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Conclusions

Conclusions

- PPETP
  - ⇒ Peer-to-peer protocol oriented to **streaming** applications
  - ⇒ Usable even with **low upload bandwidth** nodes
  - ⇒ **Integrable** with current protocols (*multicast*-like)
  - ⇒ **Stable** core, but *not frozen* yet