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Design Considerations for Faster-Than-Light (FTL) Communication

Abstract

We are approaching the time when we will be able to communicate faster than the speed of light. It is well known that as we approach the speed of light, time slows down. Logically, it is reasonable to assume that as we go faster than the speed of light, time will reverse. The major consequence of this for Internet protocols is that packets will arrive before they are sent. This will have a major impact on the way we design Internet protocols. This paper outlines some of the issues and suggests some directions for additional analysis of these issues.

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1. Introduction

We are approaching the time when we will be able to communicate faster than the speed of light. It is well known that as we approach the speed of light, time slows down. Logically, it is reasonable to assume that as we go faster than the speed of light, time will reverse. The major consequence of this for Internet protocols is that packets will arrive before they are sent. This will have a major impact on the way we design Internet protocols. This paper outlines some of the issues and suggests some directions for additional analysis of these issues.

There is a lot of discussion in the physics community about faster-than-light travel and communication. In fact, it even has a well known acronym "FTL". This acronym will be used in the remainder of this document.

FTL issues have been discussed in the scientific literature for a long time. For example, it was discussed in 1917 in the section "Velocities Greater than that of Light" on page 54 of "The Theory of the Relativity of Motion" [Tolman]. A good overall description of the effects of FTL communication can be found in [Goldberg].

[Ardavan] describes a "polarization synchrontron", which pushes radio waves faster than the speed of light. In the paper, the author explains:

> ...though no superluminal source of electromagnetic fields can be point-like, there are no physical principles preventing extended faster-than-light sources. The coordinated motion of aggregates of subluminally-moving charged particles can give rise to macroscopic polarization currents whose distribution patterns move superluminally. Further relevant progress occurred with the theoretical prediction that extended sources that move faster than their own waves could be responsible for the extreme properties of

both the electromagnetic emission from pulsars (rapidly spinning, magnetized neutron stars) and the acoustic emission by supersonic rotors and propellers.

This may be a viable approach for transmitting data FTL.

2. Protocol Design Considerations for FTL Communication

Most, if not all, Internet protocols were designed with the basic assumption that the sender would transmit the packet before the receiver received it. For example, in the Transmission Control Protocol (TCP) [RFC0793], protocol activity is shown in timing diagrams such as Figure 7:

```
    TCP A                                                TCP B

1.  CLOSED                                               LISTEN

2.  SYN-SENT    --> <SEQ=100><CTL=SYN>               --> SYN-RECEIVED

3.  ESTABLISHED <-- <SEQ=300><ACK=101><CTL=SYN,ACK>  <-- SYN-RECEIVED

4.  ESTABLISHED --> <SEQ=101><ACK=301><CTL=ACK>       --> ESTABLISHED

5.  ESTABLISHED --> <SEQ=101><ACK=301><CTL=ACK><DATA> --> ESTABLISHED
```

Basic 3-Way Handshake for Connection Synchronization

Figure 7 of RFC 793

In an FTL communication environment, this assumption is no longer true, because TCP B will receive the first SYN before TCP A transmitted it. For example, the first part of a TCP 3-way handshake in an FTL environment will look like:

```
    TCP A                                                TCP B

1.  CLOSED                                               LISTEN

2.                  <SEQ=100><CTL=SYN>               --> SYN-RECEIVED

3.  SYN-SENT    --> <SEQ=100><CTL=SYN>
```

The exact operation will depend on the difference between the backward time (i.e., from the future to the past) and the processing time to process a packet. If the processing time is greater than the backward time shift, then even though the packets are received out of order, TCP should still work due to the TCP symmetrical 3-way handshake mechanism. If the processing time is smaller than the backward time shift, then it gets much harder, as many packets will be received before they are sent. The faster the communication is above the speed of light, the more severe the problem becomes.

Assuming the first case where the processing time is equivalent or larger than the backward time shift (i.e., after an exchange of packets the backward time offset is canceled out), the TCP 3-way handshake in an FTL environment would look like:

```
    TCP A                                                    TCP B

1.  CLOSED                                                   LISTEN

2.                  <SEQ=100><CTL=SYN>                   --> SYN-RECEIVED

3.  SYN-SENT    --> <SEQ=100><CTL=SYN>

4.  ESTABLISHED <-- <SEQ=300><ACK=101><CTL=SYN,ACK>          SYN-RECEIVED

5.  ESTABLISHED     <SEQ=300><ACK=101><CTL=SYN,ACK>      <-- SYN-RECEIVED

6.  ESTABLISHED     <SEQ=101><ACK=301><CTL=ACK>          --> ESTABLISHED

7.  ESTABLISHED --> <SEQ=101><ACK=301><CTL=ACK>              ESTABLISHED
```

It shows remarkable forethought by the inventors of the TCP protocol that the 3-way handshake works in an FTL communication environment. This is due to the symmetrical nature of the 3-way handshake and its ability to deal with dropped packets. It should be possible to use dropped packets as a way to mimic an FTL communication environment. In fact, this may provide a good vehicle to analyze and test protocols to see how they will work in an FTL communication environment.

2.1. Related Issues

Additional work is needed to think about protocol design considerations when the backward time shift is much greater than the processing time. This would create challenges where it would be necessary to have received all of the data before the connection could be established. This is left to future researchers. In practical terms, this scenario isn’t likely to happen for a long time. That said, FTL communication might lead to FTL travel, where we can travel into the past. It may be necessary to start working on this yesterday.

There is a large amount of work that has been done in a related area, Delay-Tolerant Networks. For example, [RFC4838] defines an architecture for Delay-Tolerant Networks. An FTL communication environment is similar to Delay-Tolerant Networks with the major difference that the packets arrive at the destination with a negative delay. Documents that will need review include "A One-way Delay Metric for IPPM" [RFC2679] and "A Delay Bound alternative revision of RFC 2598" [RFC3248].

Congestion control algorithms will also need serious review -- specifically, how to handle negative round-trip time (RTT) on TCP congestion control or the corner case where the RTT comes out at exactly zero. Do any of the control equations include a divide-by-RTT or sqrt(RTT)? It should also be noted that there may be the possibility for significant advancements in congestion algorithms given the properties of FTL communication. Specifically, it maybe possible to stop network congestion before it starts. This could be an important new approach for congestion control researchers.

3. FTL Communication Research

FTL communication has great potential for the networking research community. It is clearly an exciting area for new research and considerable time could be spent working on it. It is very important that we fully understand all of its aspects before we know how to achieve FTL communication. Funding agencies should take this into account when allocating money and make sure that all new research projects look at FTL communication environments.

4. IETF Recommendations

The Internet Engineering Steering Group (IESG), which is the part of Internet Engineering Task Force (IETF) that manages the standards process, has area reviews as part of its review process. For example, the Security area reviews proposed protocols for security issues. The IETF Chair also has a General area that does overall reviews.

The author recommends that the IETF create a new review group to evaluate all new Internet protocols to verify that FTL communication has been taken into consideration in the design of the protocol. This would be similar to what is done to make sure that new Internet protocols are secure or are designed to run over IPv4 and IPv6. As we look forward to FTL communication, it is critical that all Internet protocols are designed to work in this environment.

Further, the author recommends that the IESG start a review process to do a detailed analysis of all existing Internet protocols to make sure they have been designed to work in FTL communication environments. For protocols that do not work in this environment, the IESG should add work items to exiting working group charters or charter new working groups to update these protocols so that they will work in FTL communication environments.

5. Security Considerations

It is early to fully understand security issues relating to FTL communication. The main issue is likely to be related to the characteristic of FTL communication that the receiver will receive a packet before it is sent. Many exploits are likely to be written to take advantage of this property. Also, given the number of exploits that are being discovered that don’t have any protections available, it may be that the malware community is already taking advantage of the properties of FTL communication.

6. Acknowledgements

Valuable comments and support were provided by Brian Carpenter and Rodney Van Meter.

7. References

7.1. Normative References

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