Multiple Paths Protocol for a Cluster Type Network

Hiroshi Mineno

Shizuoka University in Japan
Mobile Computing Environment

A mobile host works as a terminal for personal operation. Furthermore, it is also considered to form a group to co-operate with each other. This type of network is generally called an ad-hoc network or cluster type network.
Cluster Type Mobile Communications

Centralized Control

Decentralized Control

Internet

Sharing Multiple Paths
If we can use whole paths in cluster:

- The end-to-end transfer rate will be increased and the delay time will be decreased.
- The bursty traffic is dispersed into several paths and network load will be equalized.
- Transmission errors on each path are independent from errors on the other path.
- Any mobile host in cluster can freely select any kind of medium for communication with outside network.
- If one of mobile hosts in cluster hasn’t a path to outside, the host can transfer data by relaying other’s path.

**SHAKE**: **SH**Aring multiple paths protocol for **cluster type network** environment
Related Works: Traffic Dispersion

- **Dispersity Routing** (since 1975, Maxemchuk has advocated)

- **MP: Multilink Point-to-Point Protocol** (RFC1717, 1990)

These technologies of aggregating multiple communication paths and dispersing traffic into each communication path are being developed to improve the performance and efficiency of transmission.

Mobile Ad-hoc Networking System

- **Ad-hoc Wireless PC Networking System**
  (Toshiba WirelessDAN, NEC C&C Media Research Laboratories)

- **IETF MANET Working Group**

These works cover several communication methods and routing algorithms in the ad-hoc network, but there are no researches mentioned about sharing whole paths between cluster and outside network.
SHAKE protocol stack

Sharing Multiple Paths

Cluster Link

Cluster Type Network

Internet

Wired

Wireless

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We consider the network as a large buffer which has its own queue and sending rate.

For using each path effectively, it is better to leave this buffer in constant to avoid that the receiving host’s buffer is empty.
Link monitoring module

- This monitors the status of communication paths with outside. (theoretical bandwidth, throughput, transit delay, disconnection)
- Estimation of the sending rate
  (using the report from the receiver)

\[
\begin{align*}
\text{RTT} &= (\text{ST}_2 - \text{ST}_1) - (\text{RT}_2 - \text{RT}_1) \\
\text{RTT}_{\text{avg}} &= (1 - \theta)\text{RTT}_{\text{avg}} + \theta \text{RTT} \\
\text{R}_{\text{rcv}} &= (1 - \theta)\text{R}_{\text{avg}} + \theta \text{R}_{\text{rcv}} \\
\text{Buf}_{\text{cur}} &= \text{R}_{\text{rcv}}(\text{RTT}_{\text{avg}} - \text{RTT}_{\text{min}}) \\
\text{R}_{\text{snd}} &= \text{R}_{\text{rcv}} + \frac{(\text{Buf}_{\text{des}} - \text{Buf}_{\text{cur}})}{\text{Interval}}
\end{align*}
\]

- Each path’s sending rate is calculated.

ST: sender’s time stamp
RT: receiver’s time stamp
RTT: round trip time
R_{rcv}: receiver’s receiving rate
To avoid the wide fluctuation of RTT, R_{rcv}, it is estimated by using low-pass filter.
Buf_{des}: expected network buffer
Buf_{cur}: calculated current network buffer
Interval: report interval at receiving host
Path selecting module

The characters of network are different.

The distribution rate of each path must be changed according to the status of each path.

- If there are $n$ paths in cluster and the sending rate is $R_i$ of path $i$ ($i \in [1, n]$), the packet distribution rate $P_i$ of path $i$ can be calculated as follow:

$$P_i = \frac{R_i}{\sum_{k=1}^{n} R_k}$$

For example:
path A(50Kbps), path B(30Kbps), path C(20Kbps)
packet distribution rate $P_A=50\%$, $P_B=30\%$, $P_C=20\%$
Data processing module

- Divide the application data to a number of SHAKE packets.
- Add the special SHAKE header.
  (packet ID, link number, packet length, sequence number, ST1)
- Reconstruct an original data from received packets.

How to put in order the received data packets:

A packet is received from one of paths.

- Check that the packet is a data packet.
  - Yes
  - No

- Is it a correct sequence packet?
  - Yes
  - No
  - A proper processing is done.

- It is given to the application.
  - Yes
  - It is stored into the buffer temporarily.

- Check in the buffer, is there any packet with following sequence number?
SHAKE management module

- This module provides the function to form a cluster and manages all other modules.
- Path information table of all end-to-end path is made and updated when the report packet is received.
Implementation of SHAKE prototype

- We developed a simply special data transfer application on Windows95, and SHKAEM is used in the communication section of this application.
- Used data is about 4MB AVI file, the format is normally used in Microsoft Windows.
- When the application requests for sending data, path selecting module searches if the destination host is in the information table and simply uses these paths in order.
- The function which can change the packet distribution rate according to each path’s sending rate is not implemented yet.
- The data processing module is almost implemented.
Experiment 1

Data sending host
(4,139Kbyte AVI file)

Wireless LAN

Access point

LAN

Data receiving host

Experiment 2

Data sending host

Wireless LAN

Access point

LAN

Data receiving host

A cluster is formed by two mobile hosts.
In these experiments, we investigated the relationship between the amount of received data and the receiving time. And also the average of throughput.
Results of these experiments

Cluster is formed by these
- Toshiba SatellitePro420 1
  Pentium100MHz/16MB
- Mitsubishi AmitySP 1
  486DX4-75MHz/16MB

65%
20%

Amount of received data (Kbyte)

Time (s)

one path is used
average throughput
two paths are used
average throughput
two paths are used
average throughput

678Kbps
491Kbps
410Kbps
Experiment 4

Public lines with PHS terminals on PIAFS mode (32Kbps).
- Nagoya is about 100Kms away from Hamamatsu (our laboratory).
- We investigated the effect of delay between two paths.
Results of these experiment

- (1) PIAFS (Nagoya)
- (2) Average throughput (1)
- (3) PIAFS (Hamamatsu)
- (4) Average throughput (3)
- (5) 2PIAFS
- (6) Average throughput (5)

Graph showing the amount of received data (Kbyte) over time (s). The graph includes multiple lines representing different data transmission rates:

- 42 Kbps
- 26 Kbps
- 19 Kbps

The experiment was conducted in the Mizuno laboratory at Shizuoka University in Japan.
Conclusion

- We proposed SHAKE for sharing multiple paths in the cluster type network and implemented the prototype.
- Did some experiments, and expect the improvement of performance.
- The function which can change the packet distribution rate according to each path’s sending rate is not implemented, so throughput is unstable due to the delay and the effect of resequencing process.
- If we implement the function, the performance will be better.
Further Study

- Implement the function of the packet distribution rate control.
- Experiments with using various media.
- Investigate the relationship between the increase in communication link and the throughput.
- The effect of the increase in data sending hosts within a cluster.
Results(1) of these experiments

Cluster is formed by these
- Mitsubishi AmitySP 2
  486DX4-75MHz/16MB

<table>
<thead>
<tr>
<th>Amount of received data (Kbyte)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>398 Kbps</td>
<td>0 - 90</td>
</tr>
<tr>
<td>455 Kbps</td>
<td></td>
</tr>
<tr>
<td>552 Kbps</td>
<td></td>
</tr>
</tbody>
</table>

- One path is used
- Two paths are used
- Average throughput

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Related Works(1): Traffic Dispersion

- **Dispersity Routing** (since 1975, Maxemchuk has advocated)
  - For load balancing and fault handling in packet-switched networks, a message is divided into a number of submessages which are transmitted in parallel over disjoint paths in the network.

- **Vector Routing Algorithm** (proposed by Lee and Liew)
  - This algorithm encodes the K packets into N>K packets, which are sent in parallel through the network along N separate routes. When any K of the N packets are correctly received, the original message can be reconstructed.

- **MP: Multilink Point-to-Point Protocol** (RFC 1717, 1990)
  - MP is standardized by IETF and can strengthen the functions of PPP data communications between two points, and a number of virtual connections can be set up between equipment by taking advantages of characters of switched WAN service.
Related Works(2):

Mobile Distributed Co-operation System

• **Ad-hoc Wireless PC Networking System**
  (C&C Media Research Laboratories, NEC Corporation)
  – Using PHS ad-hoc networks, this system doesn’t need a base station.

• **Wireless DAN** (TOSHIBA Kansai research Laboratories)
  – This system realizes multipoint communication by using original infrared devices which is standardized by IrDA.

• **IETF MANET Working Group**
  – It’s a chartered working group to investigate and develop candidate standard Internet routing support for mobile, wireless IP autonomous segments.
The principle of Spread Spectrum communication

• The main principle of Spread Spectrum communication is that the bandwidth occupancy is much higher than usual.
• The Spreading is done by combining the data signal with a code (code division multiple access) which is independent of the transmitted data message.
• There are a couple of Spread Spectrum Techniques which can be used. The famous one is Direct-Sequence (DS), the other, Frequency-Hopping (FH) is also well-known. A combination of these two (DS/FH) offers a lot of advantages over each of two techniques and will be the basis of the proposed system.
• Frequency hopping splits the data up across the time domain. So several access points can coexist with in the same area.
Why could the throughput not be improved to twofold?

- One reason is the performance of used laptop computer, the processing speed is important.
- And second is using PCM wireless LAN card, it takes some time to process between PCM card driver and ACP driver.
- The last is that resequencing processes occur frequently.
Differences between MP and SHAKE

**MP:** Multilink Point-to-Point Protocol

- MP needs the number of network interfaces which satisfy the requested throughput. It is hard for a laptop computer to implement several network interfaces. So this protocol is not suitable for mobile computing.

**SHAKE:** Sharing multiple paths protocol

- SHAKE needs several mobile hosts, and it is hard to possess them. But according to the situation, it is easy to form a cluster and get larger transfer rate in spite of using laptop computer.