Architectural Design of Unified Multiplex Communications for One-Time Use of IP Addresses

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Outline

- Research Background
  - What is One-time use IP addresses?
- Unified Multiplex Communication Architecture
  - Overview
  - Two address types (EA and SSA)
  - Technical requirements
- Things to Do to Realize Unified Multiplex ?
  - New Technologies for Unified Multiplex Communication
  - Analysis of Interoperability
- Implementation

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Motivation

- Machine-to-Machine (Peer-to-Peer, personalized) communication will become more important for future Internet.

Problem

- Not easy to deploy servers due to security risks.

Why?

- IP address is fixed for a long time so that attacker can have much chance to try cracking.

How to solve?

- Introduce **one-time IP address** for single communication.
- Design Unified Multiplex Communication Architecture

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What are IP addresses used for?

- Currently (from beginning), IP addresses are considered to identify ***Nodes***.
- Connections are identified by using **IP addresses + port numbers** (+ protocols).
- IP addresses are used (almost) *permanently* during the node is active.

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Problems regarding Security

- Everyone agrees that…
  - Deployment of server w/ global IP address requires to consider many security risks.
  - High-level measures against security are needed.
    - Configuration of firewall, packet filters, loggings, incident reports…
    - Setting up VPN paths, authorization…
    - Careful and frequent maintenance is needed.
  - Is it really possible to all end users? **NO!**
- Are there really nothing that end users want to deploy servers? **NO!**
  - Control nodes remotely from outside.
  - Retrieve resources from outside.

Is there a way for all end users to deploy servers with easy??

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Hiding the Existence of Servers from Others

- In case of cell phone: That's easy!
  - Tell his/her phone number only to trusted people.
- WHY NOT to apply this principle to IP addresses??
  - Easy to make brute force attack in IPv4 address space.
  - Attack is much faster than phone calling.
  - Hard to regulate attack calls by administrators.
- However, IPv6 has a HUGE addressing space, i.e.,
  - Hard to brute force attack when IP address is unknown.
  - Shorten the lifetime of IP address as much as possible.
  - Changing IP address session-by-session.

NOT easy in IPv4, but possible in IPv6!!

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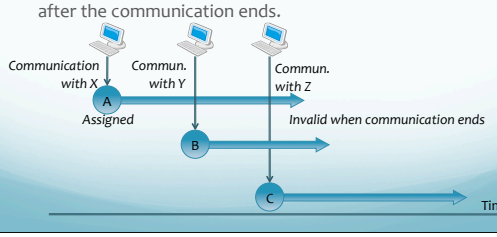
One-time IP Addresses

- IP addresses are used to identify
  - NOT for nodes, BUT for sessions!
- Assigned just before the communication starts, disposed after the communication ends.



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Security Advantages when using One-time Addresses

- IP address is ONLY valid for an associated session.
- Prevention against reverse tracking/attacking.
  - Though the IP address is known by someone, it is no longer used for any communication.
- Prevention against inference of node behavior.
  - Difficult to merge sessions having the same IP address
- Advanced authorization/authentication by using IP address only.
  - Embedding some magic numbers in IP address

Simple way to enhance security without any firewalls!!

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Unified Multiplex Communication Architecture

1 Node-1 Fixed Address ⇒ 1 Node - Multi-Floating Address

	(Current) Legacy ⇨	(Proposed) **Unified**
Number of Used Addresses	Use Only **One** Address (Basically)	Use **Multiple** Addresses
Information Dealing	General and **Share** Use **Same** Address	Specific and **Dedicated** Use **Different** Address
Service (on Servers)	Wait for **Anytime** (24hour / 365days)	Wait for **Only When** Access Expected to Come
Information Fluidity	**Fixed** (Not Changed)	**Floating** (**Changed** and **Updated**)

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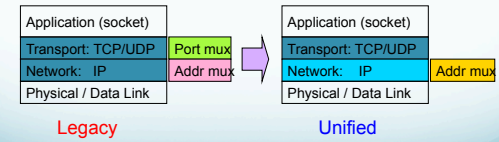
Unified Multiplex Communication Architecture

- Sessions' multiplex / distinguish operations is simplified: can be done only on the single Network Layer
- Necessary information for the operations is simplified: Destination and Source IP address information only



Legacy Unified

1: Destination Address 2: Source Address (Network Layer)

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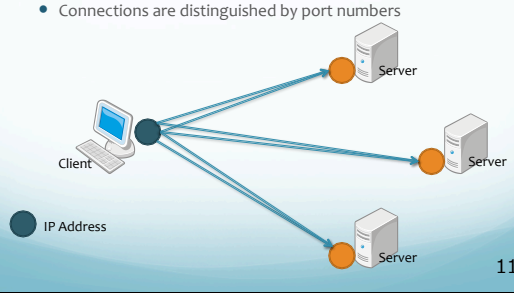
IP Addresses in Legacy Communication

- Nodes have (typically) a single IP address
  - Connections are distinguished by port numbers



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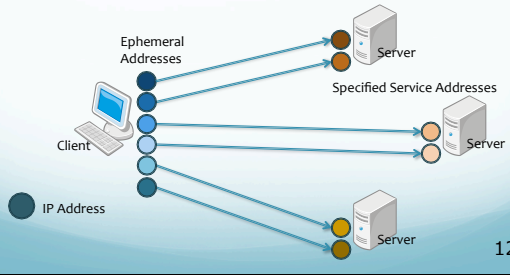
IP Addresses in Unified Multiplex Communication

- Nodes have multiple (many!) IP addresses
  - Different IP addresses are used for different connections



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Two address types on Unified Multiplex

- **EA (Ephemeral Address)** for Clients
  - Like ephemeral ports in current TCP stack.
  - Unless specifying the port number explicitly, the client automatically use an available port number .
  - Before establishing connection, the client assigns a new IP address, which is not used for any other connections.
- **SSA (Specific Service Address)** for Servers
  - Only valid for a single session.
  - Before the communication, an SSA is generated for a client to communicate with the server and notified to the client.

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Requirements for Unified Multiplex Communication

- Easy to deploy
  - Enable unified communication by updating OS software in end nodes only (no router replacements needed).
  - Support application without any updates (source modification, re-compiling).
- Co-existence with Legacy Communication nodes
  - Support gradual migration to Unified Multiplex Communication.

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Comparisons of TCP communication between Unified and Legacy

- Setting up sockets
  - Timings of binding IP address to socket are completely different.
  - IP addresses for sockets are not determined at bind() call.
- Connection identification in kernel
  - Legacy: IP addresses, port numbers, protocol.
  - Unified: IP addresses ONLY.
- Address lifetime
  - Legacy: Used permanently.
  - Unified: Invalid after the connection ends.

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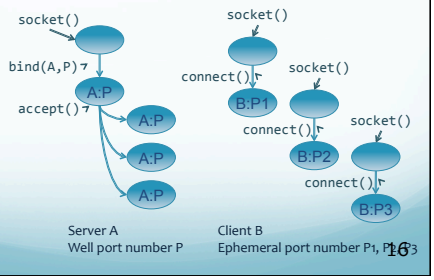
Procedure for Establishing TCP Connection (Legacy)

- Pre-determined address+port number are used for binding sockets.



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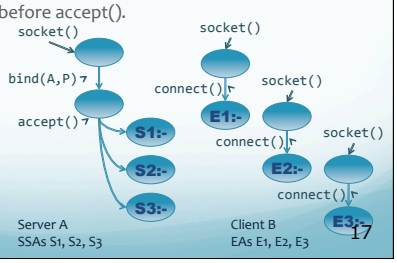
Procedure for Establishing TCP Connection (Unified)

- Port number is abolished.
- Addresses for sockets are not determined at bind(), but assigned just before accept().



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Functionalities needed for Unified Multiplex Communication

- Delayed address setting (DAS) at connection establishment
  - Set an IP address for the socket after bind() is called.
  - Introduce new (**Uncertain**) state of IP address.
  - Auto address setting for supporting applications without modification.
  - Address generation methods.
  - Introduce new TCP state for sockets without assigned IP address.
- Ignoring port numbers
  - Port number is no longer used for connection identification in PCB (Protocol Control Blocks) of kernel.
- Releasing addresses at the end of session

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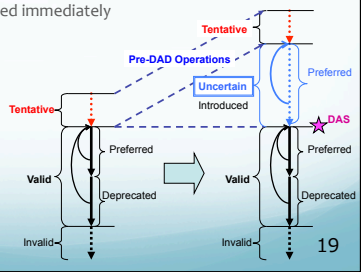
Uncertain State

- New state to represent:
  - DAD (Duplicated Address Detection) is completed but the address is not used immediately



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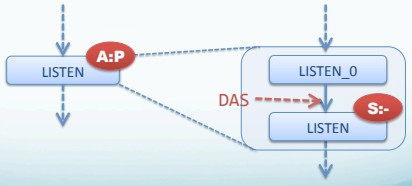
TCP State Transition

- New state (LISTEN_0) to represent:
  - Socket is listening, but no DAS'ed address is bound for accepting connection.



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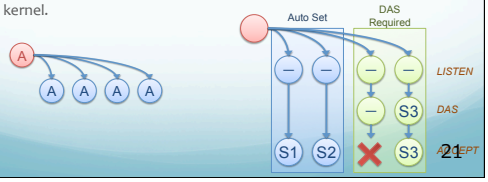
Auto Address Settings

- There is no procedure to assign EA/SSA in current applications.
  - Automatic assignment mechanism is needed for applications without any modifications.
- Two choices for address setting:
  - Automatic (Auto Set) : Suitable for most applications.
  - Manual (DAS Required) : Special address generation at outside of kernel.



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Interoperability

- Four levels of treating port numbers for communication with Legacy nodes.

Port Ignore Mode Level 0
- Completely ignore port numbers in PCB.
- Port number fields in packet header are not used.

Port Ignore Mode Level 1
- Completely ignore port numbers in PCB.
- Set port number of source node for return packet.

Port Ignore Mode Level 2
- Use port numbers in PCB of client.
- Set port number of source node for return packet.

Port Aware Mode
- Same as Legacy node
- Set fixed (LEGACY_COMPAT) port number for compatibility

Pure Unified

Pure Legacy

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Port Ignoring Level and Available Communication Styles

Mode Level	Use of port number for distinguishing sessions		Destination port number in packets	Available Communication Style Server(Addr, Port) – Client (Addr, Port)
	Server	Client		
Port ignore L0	No	No	Any	U(SSA, *) — U(EA, *)
Port ignore L1	No	No	Source port number of received packet	U(SSA, *) — U(EA, *) U(SSA, *) — L(LA, EP)
Port ignore L2	No	Yes	Source port number of received packet	U(SSA, *) — U(EA, *) U(*, *) — L(LA, EP)
Port aware	Yes	Yes	Source port number of received packet	U(*, WP) — L(LA, EP) U(*, RP) — L(LA, EP) U(*, WP) — L(LA, RP) U(*, RP) — L(LA, RP)

Node Address: U: Unified, L: Legacy; SSA: Service Specific Address, EA: Ephemeral Address, LA: Legacy Address
Port: EP: Ephemeral Port, RP: Reduced Port (LEGACY_COMPAT), WP: Well-known Port

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Implementation and Verification Status

- Unified Multiplex Communication Architecture functions have been implemented on the followings.
  - FreeBSD 6.2R FreeBSD 8.0R
  - Linux kernel 2.6.24 (implemented functions are limited)
- Without modifications of communication applications.
- Only with the kernel replacement.
- It has verified that basic functions work correctly as they are designed.

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Conclusion

- One-time use of IP address is promising for reducing security risks of nodes easily and its benefit is applicable to all end users (non experts).
- Unified Multiplex Communication Architecture
  - Realizes one-time IP address communication style with ease.
  - Has interoperability with Legacy nodes.
- Design and implementation have done in FreeBSD and Linux (partially).
- Further refinement and validation of applications are needed for wide deployment.

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