Erlang secure RPC and SSH module

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Who's talking?

- Name: Kenji Rikitake (rhee-key-tah-kay)
- '90-'92: VAX/VMS OS developer
- '92-'00: Corporate network admin
  - designed firewalls and sandbox systems
- '01-: Network security researcher
  - DNS UDP payload length (critical for DNSSEC)
  - IPv6 and NGN vulnerability issues
  - Studying Erlang for secure distributed systems

My Erlang activities

- Bitten by the Erlang bug in 2008
  - by Japanese version of Programming Erlang
- Patches accepted
  - TAI (leap second) (R13B, OTP-7609)
  - SSH aes128-cbc (R13B02, OTP-8110)
  - backporting FreeBSD patches (R13B04)
    - compiled works of Giacomo Olgeni, Paul Guyot and other FreeBSD Port contributors
  - FreeBSD Port support (lang/erlang)

Topics

- Security weakness in Erlang
- Why SSH for Erlang RPC?
- SSH protocol overview
- How Erlang supports SSH
- Prototype implementation and results
- Future plans and thoughts

Security weakness in Erlang (1)

- Clarification: Erlang/OTP actually has a lot of strength in secure programming
  - no pointer assignment
  - once-and-only-once variable assignment
  - message-passing based = minimized sharing
  - restrictive access for I/O devices
    - port, linked-in drivers, NIFs
  - OTP supports secure communication modules
    - crypto, public_key, ssh, ssl, etc.

Security weakness in Erlang (2)

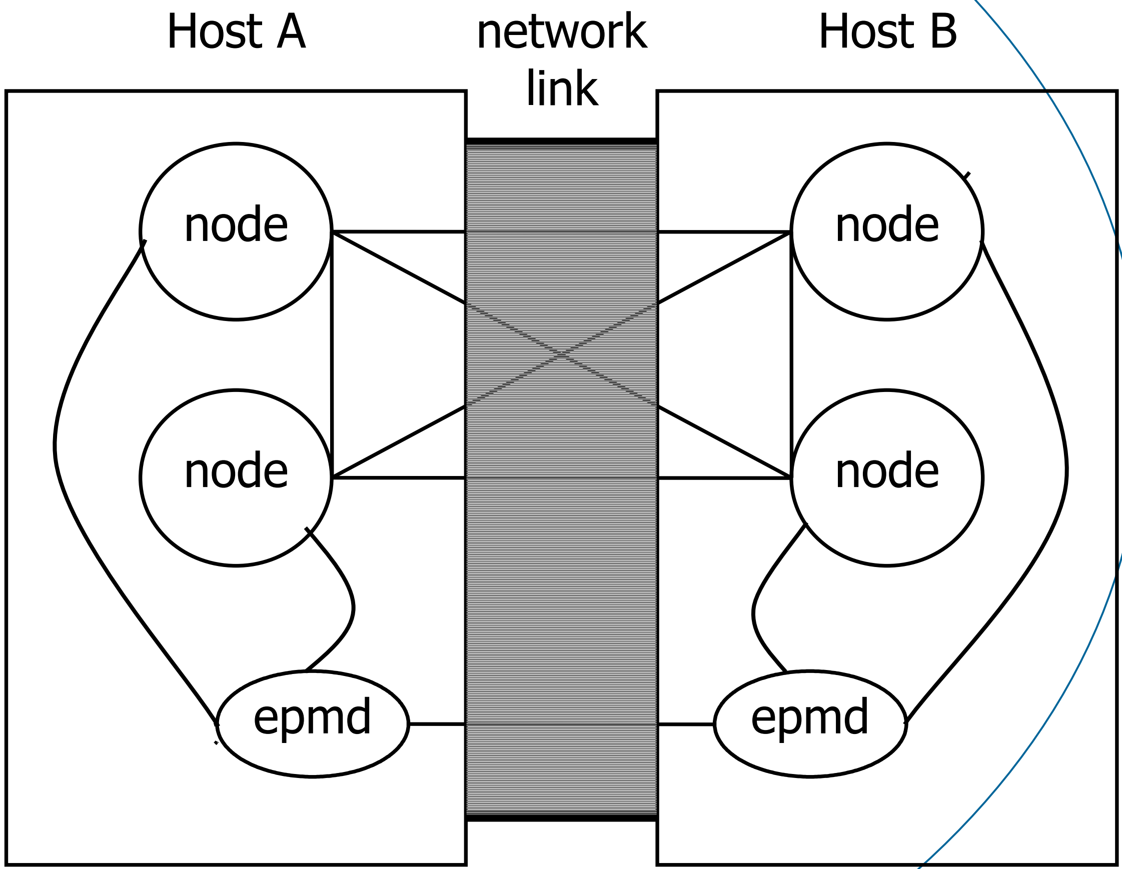
- Problem 1: inter-node TCP links are not cryptographically protected by default
  - exception: inet_ssl_dist (not well-supported)
- Problem 2: weak inter-node authentication
  - only by pre-shared plaintext cookies
- Problem 3: epmd is totally unprotected
  - and is quite hard to implement a security policy on epmd either
  - many applications depend on epmd

Security weakness in Erlang (3)

- An important issue I will not address here
  - An Erlang node assumes all registered processes in the node and other nodes are equally trustable with each other
    - Making a sandbox environment within an Erlang VM might be extremely difficult, without resolving dependency between the library modules
    - Denial-of-Service (DoS) attacks to all the nodes in the RPC network are possible once the attacker gains control in an Erlang node

Erlang/OTP inter-node RPC

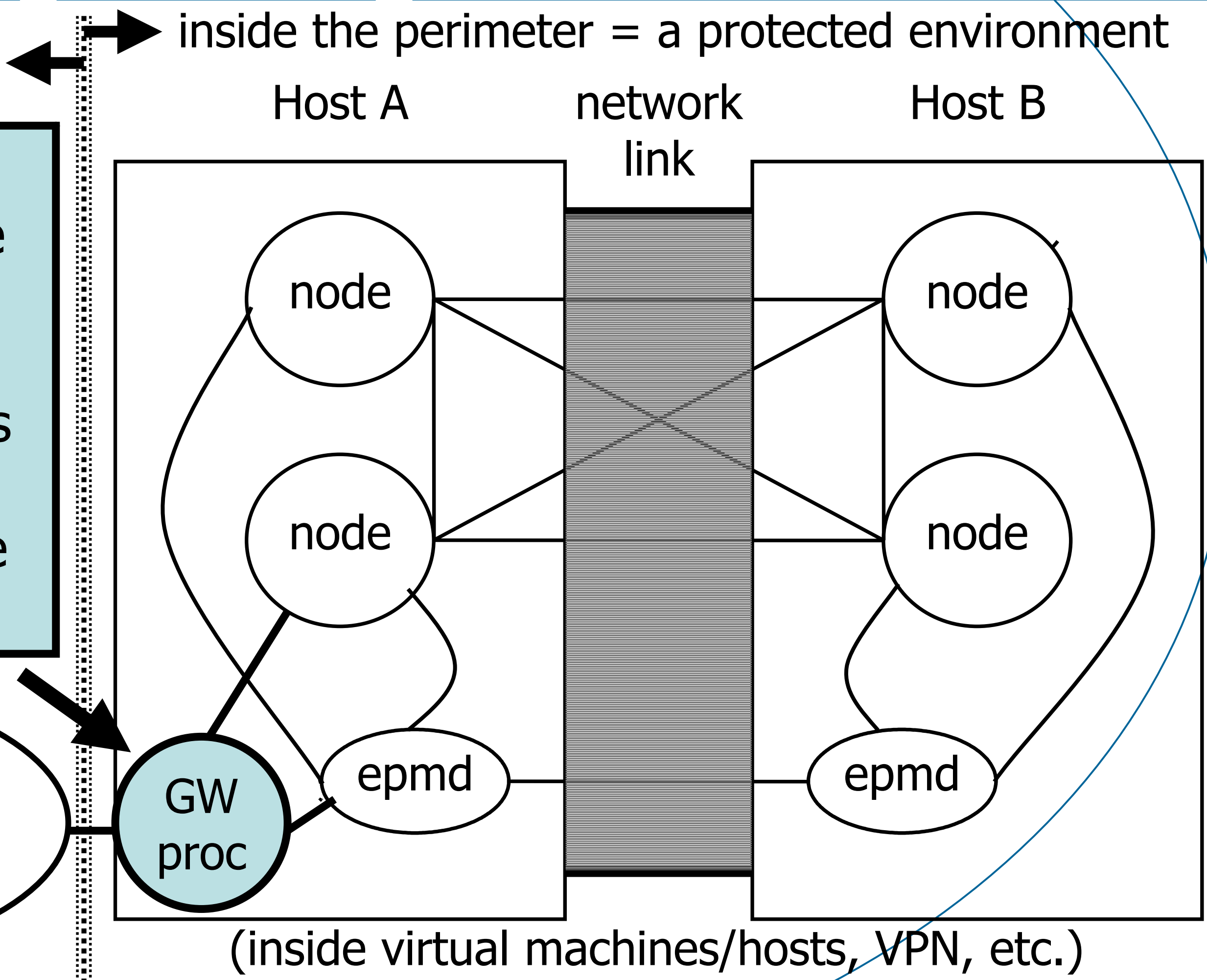
- Two kinds of links:
  - network link between hosts
  - inter-process links between the nodes and epmds
- Three types of inter-process links which have to be cryptographically protected:
  - between nodes (plain unencrypted TCP by default)
  - between nodes and epmds (usually within a host)
  - between epmds (plain unencrypted TCP only)

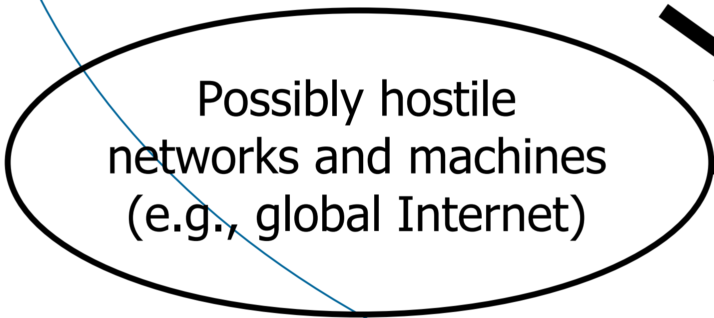


fully-connected mesh network between nodes and control link between epmd daemons

A traditional workaround for securing Erlang/OTP RPC

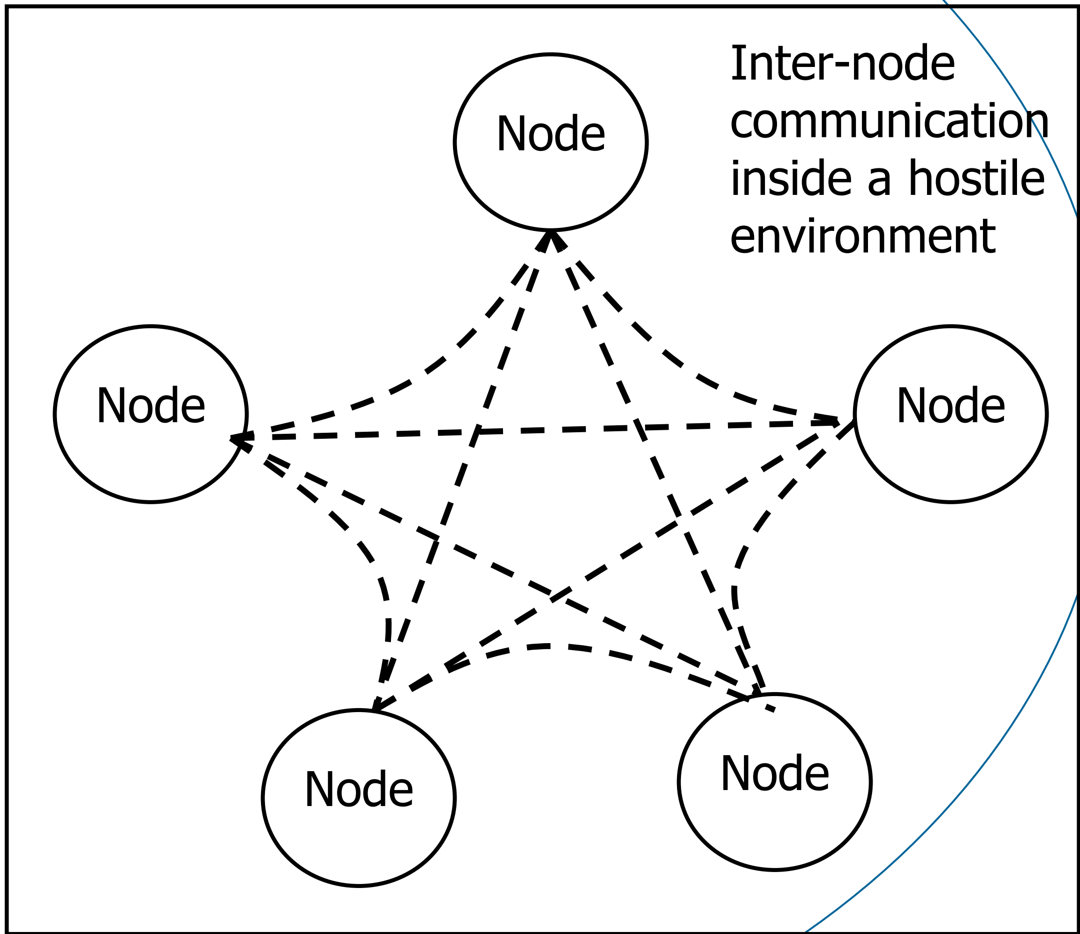
- Isolating Erlang nodes inside the perimeter is the most popular practice for protecting them
- A gateway (GW) process in an Erlang-running host is needed to communicate outside the perimeter





Another way of securing Erlang inter-node links

- If each node is connected only through a hostile environment where attackers try to eavesdrop the communication between the nodes, all communication links between the nodes must be encrypted and authenticated
- Protocol candidates for securing the links should be on the application level, such as:
  - SSL/TLS
  - SSH (Secure Shell)
- IPsec does not fit well for this purpose (only host-level policy)



Each link must be cryptographically protected

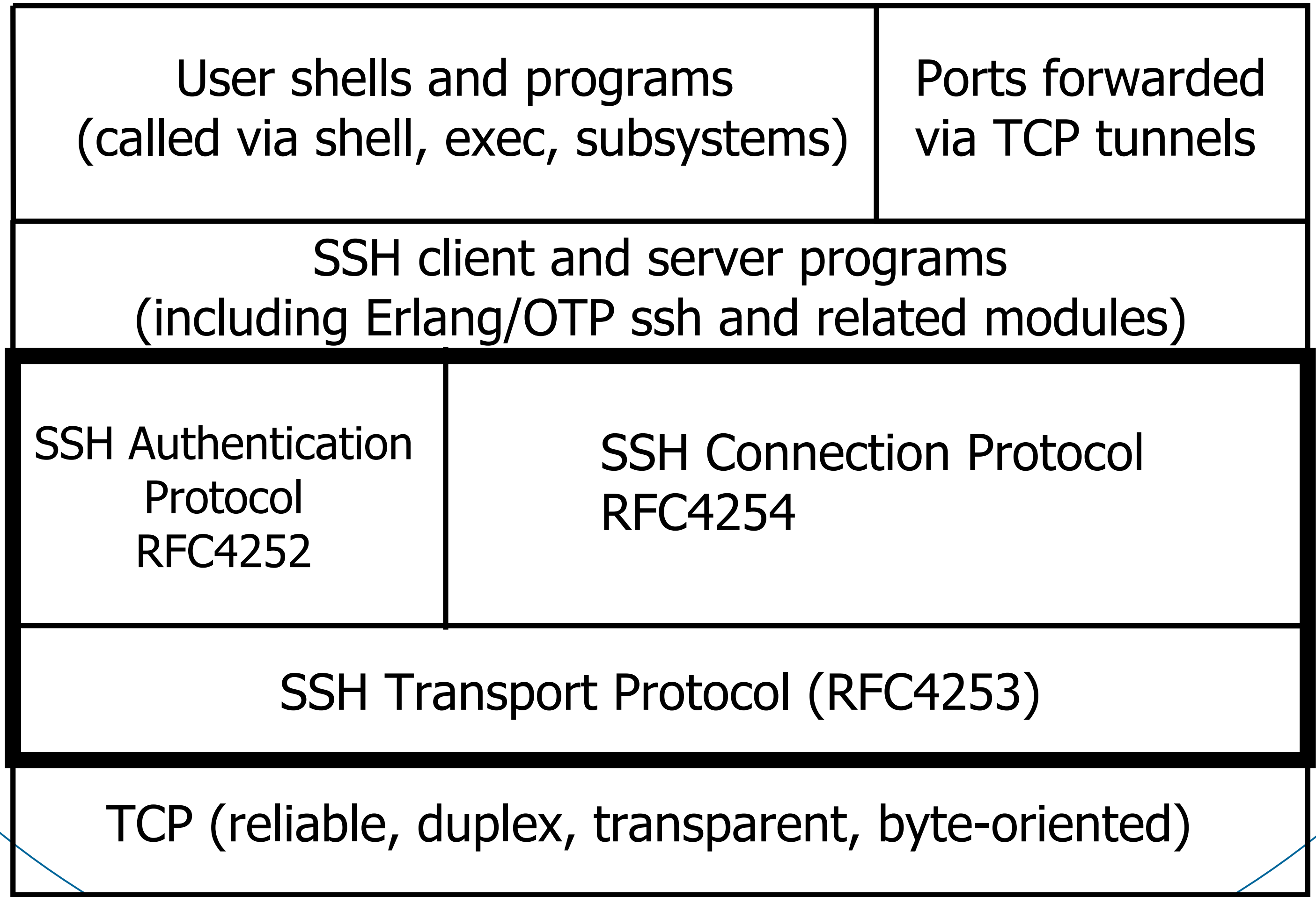
Why SSH for Erlang RPC?

- For stronger auth/encryption channels
  - SSH is easier for sysadmin than SSL
    - SSH key management is a part of daily job
  - Erlang/OTP already has full SSH capability
    - including SFTP client/server in Erlang
    - OTP ssh_channel behaviour provided
- SSH safely coexists with the current RPC
  - Remote execution over SSH will not break existing modules

Related works

- Jungerl SSH
  - I assume it's the ancestor of OTP ssh module
  - no longer maintained since 2006
  - not working on current Erlang R13B04
- RPC ideas
  - BERT-RPC: generic RPC through Erlang
    - http://www.bert-rpc.org/
  - SDIST by Dave "dizzyd" Smith (of Basho)
    - multi-level authentication and security models

SSH protocol overview (as in RFC4251)



SSH Communication Protocol (RFC4254) (1)

- Handling multiple streams of:
  - pseudo ttys (termcap, window size, signals)
  - TCP tunnels (X11/port forwarding)
- Application over SSH works as:
  - shell: interactive shell
  - exec: one-time remote execution (SCP)
  - subsystem: user-named services (SFTP)
  - Erlang ssh module supports all of these

SSH Communication Protocol (RFC4254) (2)

- Maintaining send/receive window
  - Keeping buffer windows for each direction
    - after sending message, window size decreases
    - after receiving acks, window size increases
    - This will prevent flooding without acks
      - when no ack comes the transfer will automatically stop
  - Window size is adjustable per request
    - tunable on purpose
      - interactive .vs. file transfer

SSH Transport Protocol (RFC4253)

- Server authentication (Diffie-Hellman)
- Protocol negotiation
  - Transport details
    - shared-key encryption and compression algorithms
    - HMAC for message integrity check
  - Server public-key encryption
- Binary packet format passed on to TCP
- Service requests
  - User authentication / Channel connection

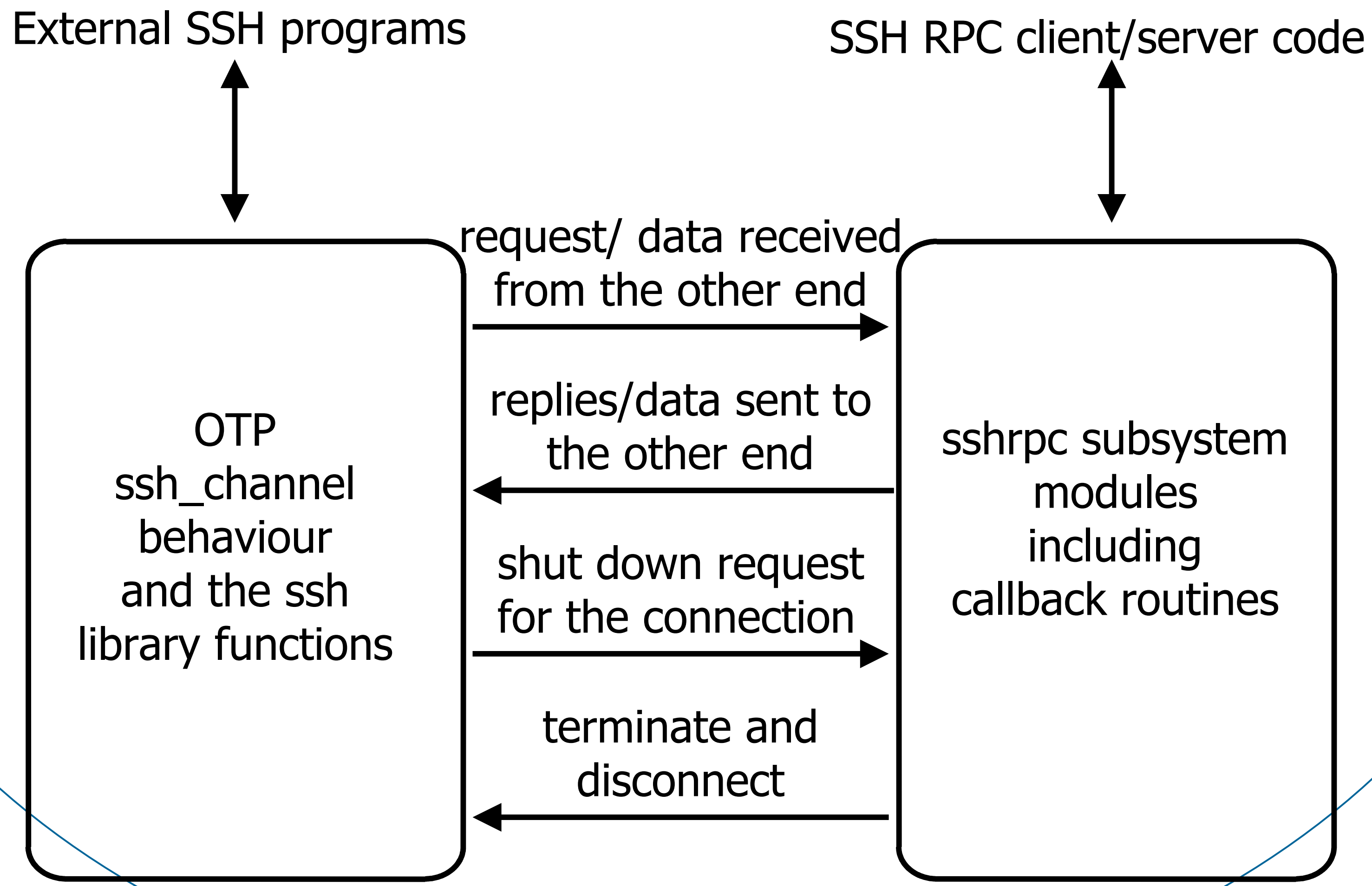
SSH Authentication Protocol (RFC4252)

- User authentication
  - after the SSH transport is established
  - available authentication methods
    - public-key: pre-distributed private and public keys
    - password: conventional password of the host
    - host-based: trusting the host auth (rlogin/rsh)
- Banner message handling

What Erlang/OTP provides

- R13B04 ssh-1.1.8 application provides:
  - password and public-key user authentication
    - CAUTION: no password encryption for private keys
  - interactive SSH shell running on a BEAM
  - one-time SSH execution on a BEAM
    - passing a string to the shell as a command
  - frameworks for SSH subsystems
    - example of SFTP client/server code
  - ssh_channel behaviour of OTP programming

interaction between user code and ssh_channel behaviour



Prototype code (already implemented)

- Remote execution of functions
  - Module:Function(Arguments)-style execution
- Non-blocking call handling
  - Synchronous call
  - Exchanged data may be more than a single SSH packet
    - subsystem-level buffering required

Implementation details (1): packet format

It's basically an Erlang External Format Term embedded with the 4-byte content length header; minimal for larger message exchange over SSH binary packets

```
<< Length:32/unsigned-big-integer,
   %% 4-byte binary (?UINT32())
   Content/binary
   %% of the Length bytes
   >>
```

Implementation details (2): message structure

- Each message is an Erlang tuple
  - marshalled with term_to_binary and de-marshalled with binary_to_term
- Two types of messages
  - {mfa, M, F, A}: command of an M:F(A)
  - {answer, Term}: reply as an Erlang Term

Implementation details (3): ssh module modification

- Added aes128-cbc encryption (R13B02)
  - RFC4253 Section 6.3 recommends this
    - OTP SSH only had 3des-cbc (a required algorithm)
    - crypto:aes_cbc_ivec/1 added
  - ssh_transport:unpack/3 bugfix needed
    - of handling zero-length packets
  - Other algorithms can be added as well
    - blowfish-cbc: already in R13B04 crypto module

Implemetation status as of 21-MAR-2010

- Basic server code complete
  - simply passing {M, F, A} to erlang:apply/3
  - multi-packet SSH message can be handled
- Basic client code complete
  - Non-blocking OTP code complete
- See my GitHub repository for the details
  - http://github.com/jj1bdx/sshrpc/

Performance evaluation

- ~500 sequential calls/second
  - System specification:
    - FreeBSD 7.2-RELEASE i386
    - Client: Core2Duo 2.2GHz memory: 2Gbytes
    - Server: Atom 1.6GHz memory: 1Gbytes
    - IPv4, 100BASE-TX
  - executed lists:seq(1,100) for 10000 times
  - CPU usage of server: 1~15%

Future plans and thoughts (1)

- ssh module needs more fixes and features
  - priority/choice of shared-key cryptography
    - current: hard-coded as [aes128-cbc, 3des-cbc]
    - more algorithms can/should be included
      - blowfish, aes192/aes256, etc.
  - Public key management
  - On R13B04 IPv6 client connection fails
    - the server/daemon code works OK
  - More comprehensive testing needed

Future plans and thoughts (2)

- RPC functions not yet implemented:
  - Asynchronous call handling
    - per-transaction ID needed
  - Spawning a remote process
  - Sending a message to a running process
  - Limiting the modules/functions to be called
- Many subsystems can be run concurrently
  - secure monitoring, control, logging, etc.

Acknowledgments (1)

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Acknowledgments (2)

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Thanks

- Questions?