Lecture 6

P2P with TomP2P

http://tomp2p.net/doc

Introduction into P2P

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0. Lecture Overview

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1. Introduction

What is TomP2P

History and project information

Introduction

TomP2P
A P2P-based high performance key-value pair storage library

- **TomP2P is an *extended* DHT**
  - Distributed hash table concept → `put(key,value) / get(key)`
  - Extended DHT operations → `put(key1,key2,value) / add(key, value)`
- **TomP2P features (v.4.1)**
  - Java6 DHT implementation with non-blocking IO
  - Replication (direct / indirect)
  - Mesh-based distributed tracker
  - Stores multiple values for one key (examples follow)
  - Storage is memory-based or disk-based

Introduction

- **TomP2P history**
  - TomP2P v1: Created in 2004 and used for a distributed DNS project
    - This version used blocking IO operations (1 thread / socket)
  - TomP2P v2: Apache MINA (java.nio framework) / 6K LoC
    - Not well designed for non-blocking operations (event-driven)
  - TomP2P v3: Redesigned for non-blocking operations
    - Switched to Netty / 14K LoC, 6K LoC JUnits
  - TomP2P v4: API refinements, new features
    - Current release (preview) 4.1
    - Latest feature (work in progress) MapReduce
    - 22K LoC, 8K LoC JUnits

Introduction

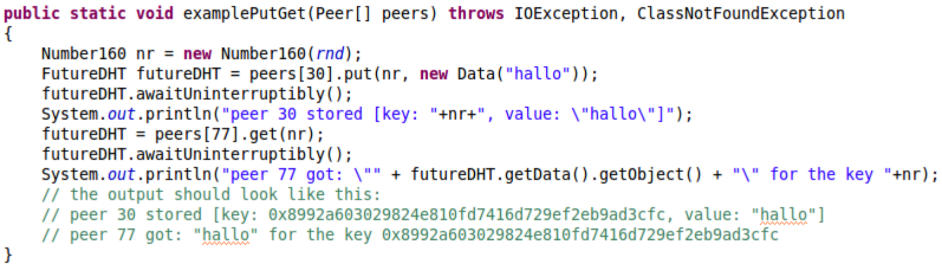
- **Academic background (CSG - UZH):**
  - Used in EU projects: EC-GIN, EMANICS, SmoothIT
  - Used in research projects: FastSS, LiveShift, PSH, B-Tracker, DRFS
- **http://tomp2p.net**
  - For questions: mailinglist (http://lists.tomp2p.net/cgi-bin/mailman/listinfo)
  - Specific questions: bocek -at- ifi.uzh.ch or tom -at- tomp2p.net
  - Documentation: http://tomp2p.net/doc/ (TomP2P v4.0)
    Overview: http://en.wikipedia.org/wiki/TomP2P
    - If something is missing, ask!
  - Development: https://github.com/tomp2p
    - Feature request possible if good reasons provided
- **Demo: how to setup TomP2P with Eclipse/git/maven**

2. Example

Example and Demo

Example

- Demo: a simple put / get example
- Package net.tomp2p.examples.Examples



```java
public static void examplePutGet(Peer[] peers) throws IOException, ClassNotFoundException
{
    Number160 nr = new Number160(rnd);
    FutureDHT futureDHT = peers[30].put(nr, new Data("hallo"));
    futureDHT.awaitUninterruptibly();
    System.out.println("peer 30 stored [key: "+nr+", value: \"hallo\"]");
    futureDHT = peers[77].get(nr);
    futureDHT.awaitUninterruptibly();
    System.out.println("peer 77 got: \"" + futureDHT.getData().getObject() + "\" for the key "+nr);
    // the output should look like this:
    // peer 30 stored [key: 0x8992a603029824e810fd7416d729ef2eb9ad3cfc, value: "hallo"]
    // peer 77 got: "hallo" for the key 0x8992a603029824e810fd7416d729ef2eb9ad3cfc
}
```

3. Fundamental Concepts

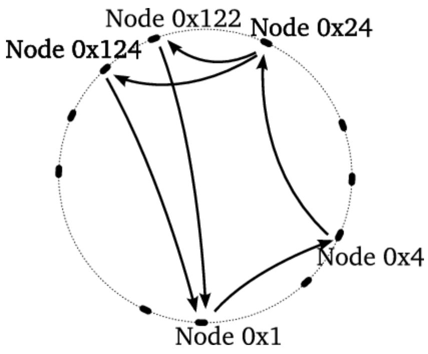
XOR-based iterative routing

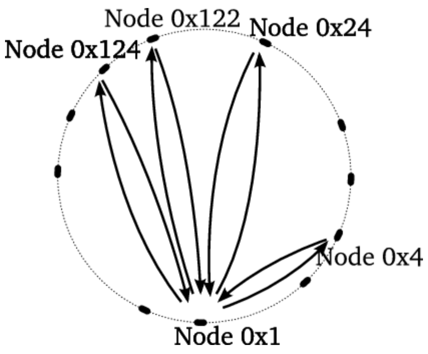
Futures

API Overview

Fundamental Concepts

- Recursive routing vs. iterative routing





+ online status update

- faulty peers cause delay

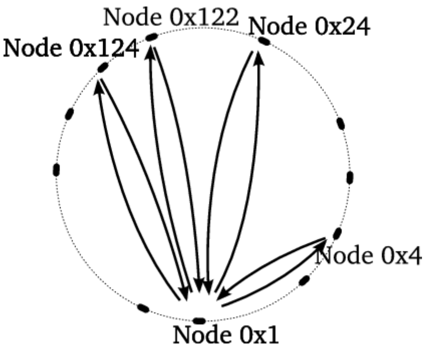
+ control

- neighbor maintenance

Fundamental Concepts

- **TomP2P: iterative XOR-based routing**
  - Node and data item unique 160bit identifier
  - Keys are located on the nodes whose node ID is closest to the key
  - Search for a key:
    - Lookup in neighbor table for closest peer (*e.g.* peers with ID: 0x1, 0x2, 0x3, 0x4)

My ID	Neighbor ID	Distance (XOR)
1	2	3
1	3	2
1	4	5



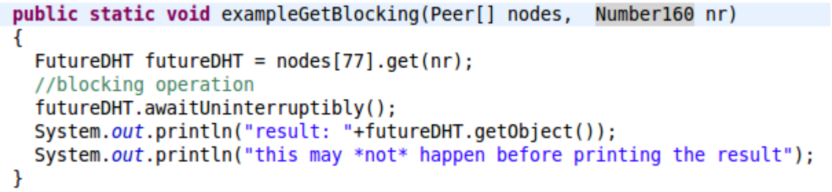
    - Difference to Pastry: one metric, no leaf set / routing table

Fundamental Concepts

- **TomP2P iterative XOR-based routing**
  - Neighbors stored in 159 “bags”, bag has capacity c (Kademlia, c=20)
  - Routing takes O(log n) → M03, slides 12
  - By default UDP, message header 56 bytes
  - Configuration options (RoutingConfiguration.java)
    - directHits – used for get() operations. (routing sends digest)
    - forceTCP – use TCP instead of UDP
    - maxSuccess, maxFailure – stop conditions
    - parallel – number of parallel connections
    - maxNoNewInfoDiff – stop condition. Stops if no new information was reported. Difference to minimumResults (e.g. for `get(key)`)
  - For the CT - don’t worry, default settings are fine ☺

Fundamental Concepts

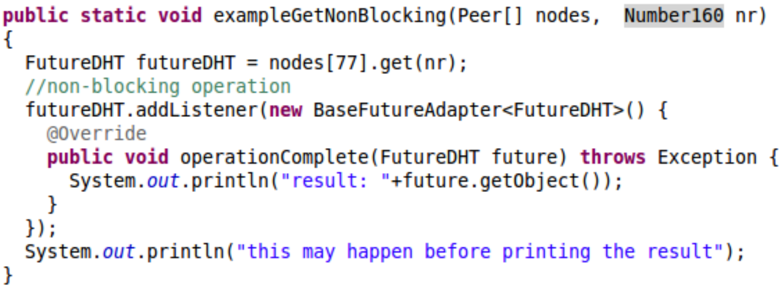
- **All distributed operations use futures**
- **Future objects**
  - Keeps track of future events, while the “normal” program flow continues → `addListener()` or `await()`
  - `await()`: Operations are executed in same thread
  - `addListener()`: Operations are executed in same or other thread
- **Demo: blocking operation (net.tomp2p.examples.Examples)**



```java
public static void exampleGetBlocking(Peer[] nodes,  Number160 nr)
{
  FutureDHT futureDHT = nodes[77].get(nr);
  //blocking operation
  futureDHT.awaitUninterruptibly();
  System.out.println("result: "+futureDHT.getObject());
  System.out.println("this may *not* happen before printing the result");
}
```

Fundamental Concepts

- **Demo: non - blocking operation (net.tomp2p.examples.Examples)**
  - New utilities necessary (loops as recursions)
  - Advise: use `addListener(…)` as much as possible!
  - `operationComplete(…)` must be **always** called



```java
public static void exampleGetNonBlocking(Peer[] nodes,  Number160 nr)
{
  FutureDHT futureDHT = nodes[77].get(nr);
  //non-blocking operation
  futureDHT.addListener(new BaseFutureAdapter<FutureDHT>() {
    @Override
    public void operationComplete(FutureDHT future) throws Exception {
      System.out.println("result: "+future.getObject());
    }
  });
  System.out.println("this may happen before printing the result");
}
```

Fundamental Concepts

- **Future utilities**
  - `FutureForkJoin(int nr, boolean cancel, K... Forks)`
    - Joins already “forked” futures. Waits until all or `nr` future finished. If nr reached, futures may be cancelled (e.g. abort download)
  - `FutureLateJoin(int nrMaxFutures, int minSuccess)`
    `FutureLaterJoin()`
    - No need to add the futures in the constructor, can be added later
  - `FutureWrapper()`
    - A placeholder for futures that are created later
- **ForkJoin in Java7**
  - Fork and join framework – future utilities in TomP2P focus on join, forking is done “manually”

Fundamental Concepts

- **Fun with futures: loops**

```
Future loop() {
           Future future = new Future();
           recLoop(future);
           return future;
}

void recLoop(Future future) {
           int active = 0;
           for (int i = 0; i < parallel; i++) {
                      //if future finished, it will be set to null
                      if (futureResponses[i] == null) {
                                 active++;
                                 futureResponses[i] = doSomething();
                      }
                      else if (futureResponses[i] != null) active++;
           }
           if (active == 0) future.weAreDone();
           FutureForkJoin<FutureResponse> fp = new FutureForkJoin<FutureResponse>(1, futureResponses);
           fp.addListener(new BaseFutureAdapter<FutureForkJoin<FutureResponse>>() {
                      @Override
                      public void operationComplete(FutureForkJoin<FutureResponse> future)
                      throws Exception {
                                 boolean finished = evaluate(future);
                                 if(finished) future.weAreDone();
                                 else recLoop(future);
                      }
           });
}
```

Fundamental Concepts

- **API Overview: Peer.java**
  - Basic methods for DHTs
    - `put(key, value)`,`get(key)`
  - Additional methods in TomP2P:
    - For initial connection: `boostrapBroadcast()` / `boostrap(Ipaddress, port)` / `discover(IPaddress, port, port)`
    - Requires to specify `set*DataReply(…)`: `send(peeraddress, value)` / `send(peerconnection, value)` / `send(key, value)`
    - Data manipulation: `add(key, value)` / `putIfAbsent(key, value)` / `digest(key)` / `remove(key)`
    - Tracker operations: `getFromTracker(key)` / `addToTracker(key, value)`
    - Used mostly internally `parallelRequests(…)`

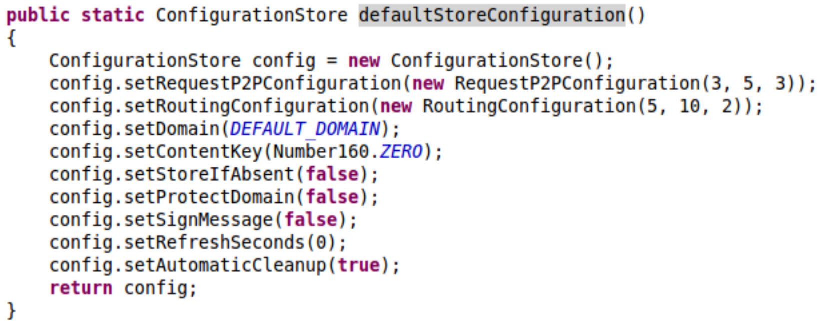
Fundamental Concepts

- **Configurations used in the API**
  - TomP2P can store multiple values for a key
    - `put(location_key, content_key, value)` → content_key specified in Configurations
    - `get(location_key)`
      → returns a map with [`content_key, value`]
    - `add(location_key, value)` → is translated to `put(location_key, hash(value), value)`
  - TomP2P support domains
    - Avoid collision for same keys
    - Domains are used for protection (more details later)
    - Domains specified in Configurations
    - `put(key, domain, value)` → `get(key,domain)`

Fundamental Concepts

- **Configurations Example**

```
Number160 nr = new Number160(rnd);
ConfigurationStore cs = Configurations.defaultStoreConfiguration();
cs.setDomain(Number160.createHash("my_domain"));
cs.setContentKey(new Number160(11));
FutureDHT futureDHT = peers[30].put(nr, new Data("hallo"), cs);
```



```
public static ConfigurationStore defaultStoreConfiguration()
{
    ConfigurationStore config = new ConfigurationStore();
    config.setRequestP2PConfiguration(new RequestP2PConfiguration(3, 5, 3));
    config.setRoutingConfiguration(new RoutingConfiguration(5, 10, 2));
    config.setDomain(DEFAULT_DOMAIN);
    config.setContentKey(Number160.ZERO);
    config.setStoreIfAbsent(false);
    config.setProtectDomain(false);
    config.setSignMessage(false);
    config.setRefreshSeconds(0);
    config.setAutomaticCleanup(true);
    return config;
}
```

5. Components with Examples

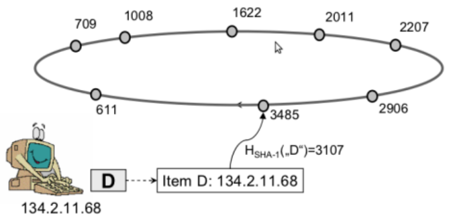
DHT

Tracker

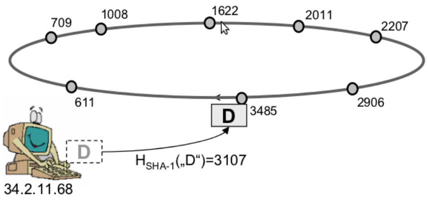
Components with Examples

- **DHT vs. Tracker**
  - M03, slide 23: DHT “stored by value” – direct storage
  - M03, slide 24: Tracker “stored by reference” – indirect storage

indirect (Tracker)



direct (DHT)

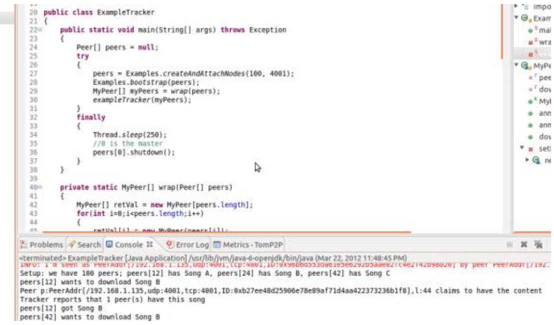


Components with Examples

- **B-Tracker**
  - Centralized tracker – one peer gets traffic
  - DHT: store reference on 20 peers – 20 peers gets traffic
  - PEX: exchange information every minute (push)
  - B-Tracker, every downloading peer becomes a tracker → forms mesh
    - Better balance of load
    - To avoid duplicates send compressed list of known peers
  - B-Tracker in TomP2P enabled by default
  - Currently tests with B-Tracker in Vuze

Components with Examples

- **Demo: Tracker with exchange of popular items (net.tomp2p.examples.ExampleTracker)**
  - Creat 100 peers, 3 peers have initially each a song
  - M03 slide 26: peer joining / bootstrap



```java
public class ExampleTracker
{
    public static void main(String[] args) throws Exception
    {
        Peer[] peers = null;
        try
        {
            peers = Examples.createAndAttachNodes(100, 4001);
            Examples.bootstrap(peers);
            MyPeer[] myPeers = wrap(peers);
            exampleTracker(myPeers);
        }
        finally
        {
            Thread.sleep(250);
            //0 is the master
            peers[0].shutdown();
        }
    }

    private static MyPeer[] wrap(Peer[] peers)
    {
        MyPeer[] retVal = new MyPeer[peers.length];
        for(int i=0;i<peers.length;i++)
        {
            retVal[i] = new MyPeer(peers[i]);
```

```
<terminated> ExampleTracker [Java Application] /usr/lib/jvm/java-6-openjdk/bin/java (Mar 22, 2012 11:48:45 PM)
INFO: I'm seen as PeerAddr[/192.168.1.135,udp:4001,tcp:4001,ID:[illegible]] by peer PeerAddr[/192.
Setup: we have 100 peers; peers[12] has Song A, peers[24] has Song B, peers[42] has Song C
peers[12] wants to download Song B
Peer p:PeerAddr[/192.168.1.135,udp:4001,tcp:4001,ID:0xb27ee48d25906e78e89af71d4aa422373236b1f8],l:44 claims to have the content
Tracker reports that 1 peer(s) have this song
peers[12] got Song B
peers[42] wants to download Song B
```

Components with Examples

- **Demo: Tracker with exchange of popular items**
  - Although demo uses `await()`, try not to use it
- **Demo: Store popular items in DHT (net.tomp2p.examples.ExampleDHT)**
  - Tracker vs. DHT what is better for the CT? You decide!
- **Further interesting aspects for the challenge task:**
  - Automate downloads
  - Suggestions evaluated by the user
  - How to do this more anonymous: music list from a peer is known
  - Incentives
  - Spamming the system with bogus suggestions

6. Advanced Topics

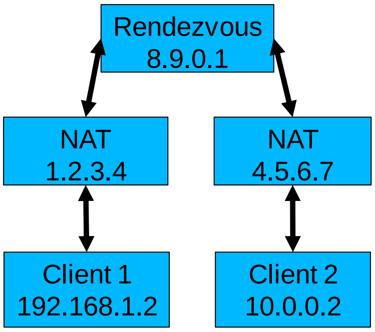
NAT (UPNP/NAT-PMP)
Security
Replication
SimGrid integration
Direct data connection / persistent connection
Android

Advanced Topics

- **NAT**
  - Network Address Translation – breaks end-to-end
  - “If nothing else, [NAT] can serve to provide temporarily relief while other, more complex and far-reaching solutions are worked out” (RFC 1631 - The IP Network Address Translator (NAT))
  - Easy solutions: UPNP / NAT-PMP
    - Both configure port forwarding, but UPNP is more
    - UPNP: discover devices - uses broadcasting to find router (Simple Service Discovery Protocol)
    - UPNP: configure devices - uses HTTP and XML to configure portforwarding (Internet Gateway Device Protocol)
    - NAT-PMP: protocol made for configuring port-forwarding, but no discover (how to find router?)

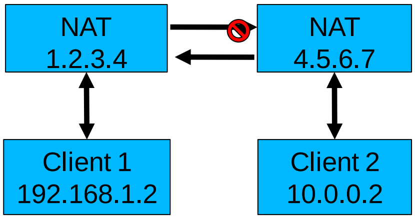
Advanced Topics

- **NAT: Difficult solution: rendezvous / relay peer which does “hole punching”, in worst case relay traffic.**
- Hole punching
  - ▶ Client 1 wants to connect to Client 2 (both clients maintain connection to Rendezvous)
  - ▶ Client 1 sends connection request to Rendezvous → Redezvous send connection request to Client 2 and the outgoing port X that Client 1 will use and send to Client 1 what outigoing port Y will be used by Client 2 (guess!)



Advanced Topics

- Hole punching
  - ▶ Client 1 sends request to NAT 4.5.6.7 that will fail – no mapping, however, Client 1 creates a mapping with that request
  - ▶ Client 2 send a request to Client 1 (1.2.3.4:X) – success!



Mapping for NAT 1.2.3.4 (Client 1)		
192.168.1.2:4000	1.2.3.4:X	4.5.6.7:Y

Mapping for NAT 4.5.6.7 (Client 2)		
10.0.0.2:5000	4.5.6.7:Y	1.2.3.4:X

Advanced Topics

- **NAT example in TomP2P, the easy solution**
  - TomP2P supports NAT-PMP and UPNP, no holepunching or relaying
  - Before bootstrap: `peer.discover(PeerAddress);`
  - How it works: (1) send request how others peers sees our IP
    - If other peers sees the same IP as we see, we are fine
    - If not, we are most likely behind a NAT
  - (2) do UPNP, if it fails, do NAT-PMP, if it fails, no connection
  - (3) If it works test connection, send request to other peer to contact us using the port we just set up.
  - (4) If we get contacted by this peer within 5 sec, port-forwarding works.
  - Manual setup possible using `Bindings.java`
- **No Demo, did not bring my NAT device**

Advanced Topics

- **Security in TomP2P**
  - Signature-based, no data encryption
  - Messages are signed using SHA1 with DSA
  - Sybil attacks!
    - This attack creates large number of identities, may collude
- **How to prevent Data from being overwritten**
  - Domain and entry protection, requires cooperation
  - `StorageGeneric.setProtection(…)`

For domains and entries		
protectionEnabled	ALL	NONE
protectionMode	NO_MASTER	MASTER_PUBLIC_KEY

Advanced Topics

- **Domain protection**
  - Set publick key `new PeerMaker(PublicKey)`
    - Enable=ALL, Mode=NO_MASTER → every peer can protect domains, first come first served
    - Enable=NONE, Mode=NO_MASTER → no peer can protect domains
    - Enable=ALL, Mode=MASTER_PUBLIC_KEY → every peer can protect domains, the owner can claim domain
    - Enable=NONE, Mode=MASTER_PUBLIC_KEY → no peer can protect domains except the owner
  - Owner of domain 0x1234 is peer where 0x1234 == hash(public_key)
  - Same concept for entries
  - Tracker should have no domain protection and entry protection set to Enable=NONE, Mode=MASTER_PUBLIC_KEY → WiP
- **Demo**

Advanced Topics

- **Demo 1 (net.tomp2p.examples.ExampleSecurity):**
  - 3 peers, all with public keys
  - Setup for domains: Enable=ALL, Mode=MASTER_PUBLIC_KEY
  - (1) peer1 stores data in domain2 → success
  - (2) peer3 wants to store data in domain2 → fail
  - (3) peer2 wants to store data in domain2 → success
- **Demo 2 (net.tomp2p.examples.ExampleSecurity):**
  - 3 peers, all with public keys
  - Setup for domains: Enable=NONE, Mode=MASTER_PUBLIC_KEY
  - (1) peer1 stores data in domain2 → success
  - (2) peer3 wants to store data in domain2 → success
  - (3) peer2 wants to store data in domain2 → success
  - (4) peer3 wants to store data in domain2 → fail

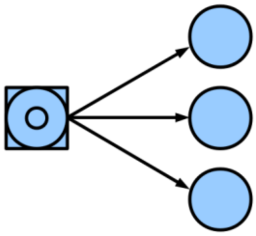
Advanced Topics

- **Replication**
  - Enough replicas
  - Direct replication
    - Originator peer is responsible
    - Periodically refresh replicas
    - Example: tracker that announces its data

□ Responsible for X

◉ Originator of X

○ Close peers to X



- **Problem**
  - Originator offline → replicas disappear. Content has TTL, e.g. `data.setTTLSeconds(15)`

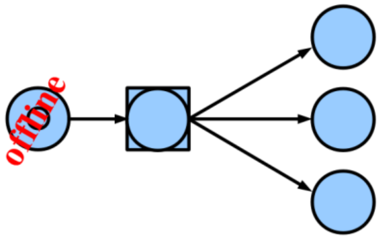
Advanced Topics

- **Indirect Replication**
  - The closest peer is responsible, originator may go offline
    - Periodically checks if enough replicas exist
    - Detects if responsibility changes

□ Responsible for X

◉ Originator of X

○ Close peers to X



- **Problem**
  - Requires cooperation between responsible peer and originator
  - Multiple peers may think they are responsible for different versions → eventually solved

Advanced Topics

- **Replication Demo (net.tomp2p.examples.ExampleDirectReplication)**
  - Direct replication – for `put()` and `add()`
    - `ConfigurationStore.setRefreshSeconds(2);`
    - Stop replication if in progress: `futureDHT.shutdown();`
  - Direct replication for `remove()`
    - `ConfigurationRemove.setRefreshSeconds(2);`
    - `ConfigurationRemove.setRepetitions(2);`
    - Stop replication after 4 seconds, 2 repetitions
  - Indirect replication (net.tomp2p.examples.ExampleIndirectReplication)
    - Set when creating peers
    - `PeerMaker.setEnableIndirectReplication(true);`
    - Two types of events: (1) peer learns about closer peer (2) peer checks frequently for enough replicas

Advanced Topics

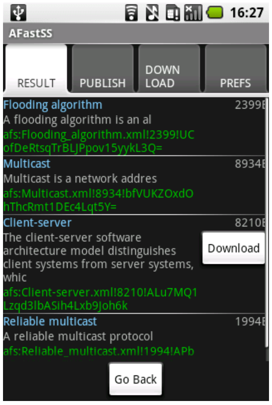
- **SimGrid integration**
  - Scalable simulation of distributed systems
  - Publish over 100 papers that include SimGrid
  - SimGrid vs. real network
  - For TomP2P: simulates network with many peers
    - Defined in XML files: `platform.xml` and `deployment.xml`
  - Logging in console
  - Current issue in jMSG: threads, threads, threads!
- **Demo: how to use it with TomP2P**
  - Get the Eclipse workspace: http://tomp2p.net/dev/simgrid/ (Linux x64)
  - 10’000 peers are OK, to simulate more, kernel parameter tuning

Advanced Topics

- **Direct data and persistent connections**
  - All connections in TomP2P are RPC and very short-lived
    - Open connection – request – reply – close connection
  - Direct data as seen in the tracker example → keep alive
  - Direct `send(PeerAddress, …)` or with routing `send(key, …);`
  - Always use `setObjectDataReply()` or `setRawDataReply()`
    - Object serializes object to byte[] (easy)
    - Raw exposes (Netty) buffer to the user for your own protocol (more work)
  - Persistent connections set by the user
    - Only for direct send `send(PeerAddress, …)`
- **Demo with persistent connections (net.tomp2p.examples.ExamplePersistentConnection)**

Advanced Topics

- **TomP2P with Android (early research)**
  - CSG: early adopter



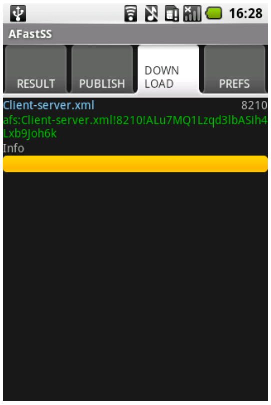
16:27
AFastSS
RESULT | PUBLISH | DOWN LOAD | PREFS

Flooding algorithm 2399E
A flooding algorithm is an al
afs:Flooding_algorithm.xml!2399!UCofDeRtsqTrBLJPpov15yykL3Q=

Multicast 8934E
Multicast is a network addres
afs:Multicast.xml!8934!bfVUKZOxdOhThcRmt1DEc4Lqt5Y=

Client-server 8210E
The client-server software architecture model distinguishes client systems from server systems, whic
afs:Client-server.xml!8210!ALu7MQ1Lzqd3lbASih4Lxb9Joh6k

Reliable multicast 1994E
A reliable multicast protocol
afs:Reliable_multicast.xml!1994!APb



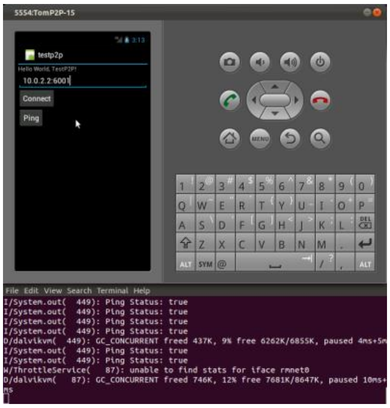
16:28
AFastSS
RESULT | PUBLISH | DOWN LOAD | PREFS

Client-server.xml 8210
afs:Client-server.xml!8210!ALu7MQ1Lzqd3lbASih4Lxb9Joh6k
Info

Advanced Topics

- **TomP2P with Android ICS 4.0.3**
  - Latest Android is ~Java6 (source code) compatible
  - Extra work (permissions, IPv4)
  - TomP2P with multiple emulators
    - Redirect ports!
    - telnet to all emulators:

      ```
      redir add udp:x:y
      redir add tcp:x:y
      ```
    - Connect to 10.0.2.2!
- **TomP2P on Android: Demo with local peers**



```
I/System.out(  449): Ping Status: true
I/System.out(  449): Ping Status: true
I/System.out(  449): Ping Status: true
I/System.out(  449): Ping Status: true
D/dalvikvm(  449): GC_CONCURRENT freed 437K, 9% free 6262K/6855K, paused 4ms+5m
I/System.out(  449): Ping Status: true
I/System.out(  449): Ping Status: true
W/ThrottleService(   87): unable to find stats for iface rmnet0
D/dalvikvm(   87): GC_CONCURRENT freed 746K, 12% free 7681K/8647K, paused 10ms+
ms
```

7. References

4. References

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- **Sybil attack**
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- **Sybil attack counter measurements**
  - Raul Landa , David Griffin , Richard G. Clegg , Eleni Mykoniati , Miguel Rio. "A Sybilproof Indirect Reciprocity Mechanism for Peer-to-Peer Networks"
- **B-Tracker**
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- **Fork/Join in Java**
  - http://docs.oracle.com/javase/tutorial/essential/concurrency/forkjoin.html
- **Hole punching**
  - http://www.brynosaurus.com/pub/net/p2pnat/