CS551
Final Project Part (1)

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Peer-to-Peer File Sharing System

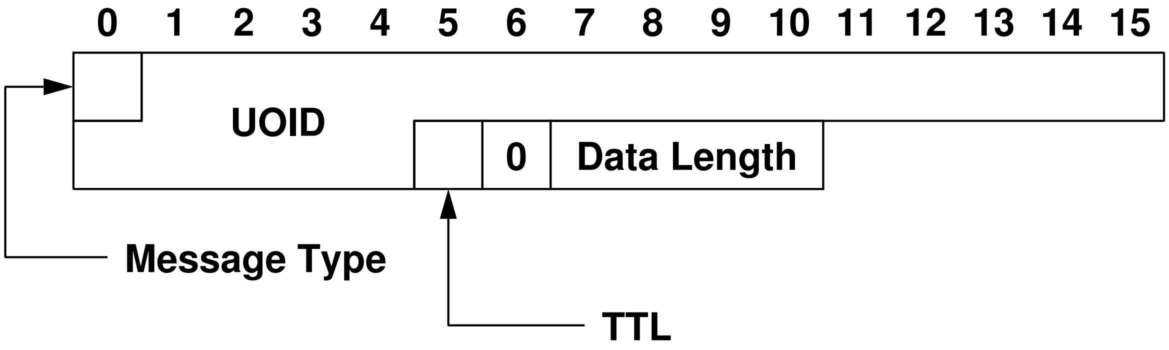
- *Peer-to-peer:* if one is using the system, one must be sharing his/her resources
- Application layer network named *SERVANT*
  - the words "packet" and "message" are interchangable
  - messages are sent via flooding (no loops)
  - reply to messages are sent along the path it was received
- Bi-directional connections between neighbors
  - A→B and B→A must use the same connection
- Two types of nodes
  - *beacon nodes:* well known addresses that every node knows, fully connected to form the core of the network
  - regular nodes
  - operationally, beacons are just like regular nodes (except a beacon does not need to *join* the network)

Message Types

- Part (1): form and maintain the network (45% project grade)
  - Join
  - Hello
  - Keepalive
  - Notify
  - Status
  - Check (keep things connected)
- Part (2): think google and napster (35% project grade)
  - Store
  - Search
  - Get
  - Delete

Message Format

- **Common header**



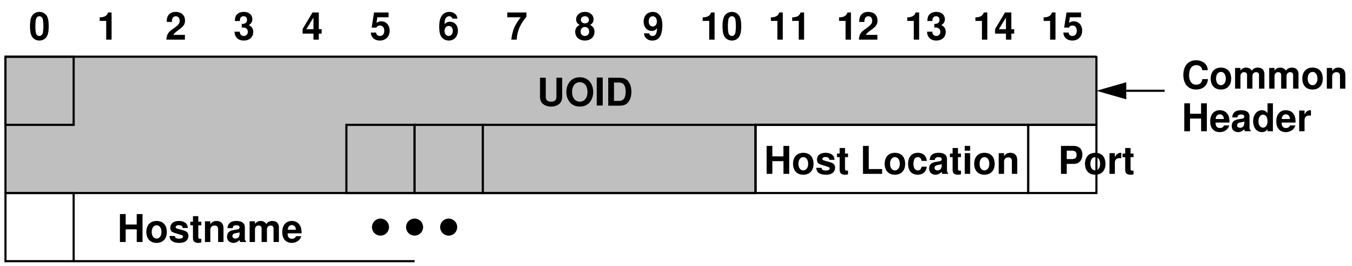
UOID

Probabilitically unique

```
char *GetUOID(
        char *node_inst_id,
        char *obj_type,
        char *uoid_buf,
        int uoid_buf_sz)
{
    static unsigned long seq_no=(unsigned long)1;
    char sha1_buf[SHA_DIGEST_LENGTH], str_buf[104];

    sprintf(str_buf, "%s_%s_%1ld",
            node_inst_id, obj_type, (long)seq_no++);
    SHA1(str_buf, strlen(str_buf), sha1_buf);
    memset(uoid_buf, 0, uoid_buf_sz);
    memcpy(uoid_buf, sha1_buf,
            min(uoid_buf_sz,sizeof(sha1_buf)));
    return uoid_buf;
}
```

Requests

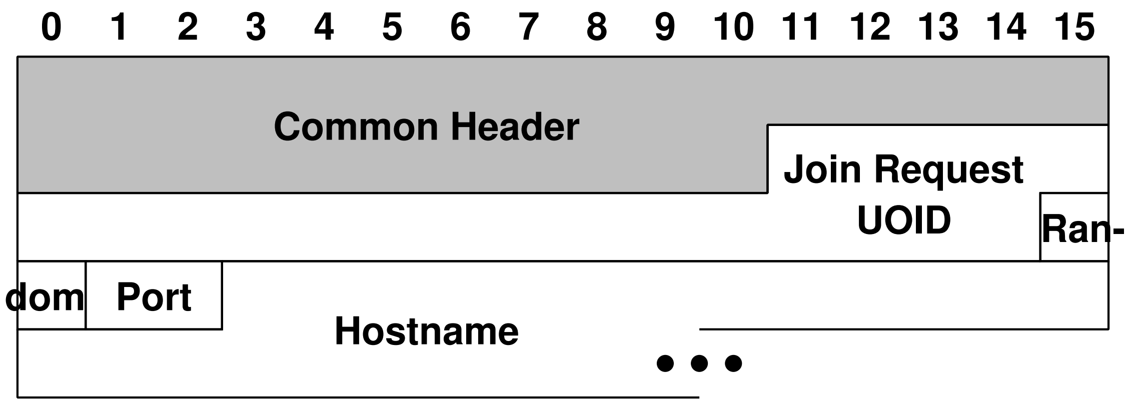
- For example, join request



- Requests are *flooded* to the entire SERVANT network
  - anonymity of the message senders and message receivers
  - must avoid loops
  - nodes must *cache* a copy of any flooded message
    1) for *loop detection*, i.e., drop duplicate messages based on UOID
    2) to *route a response message* to the originator of the corresponding request message
  - message cache expires after *MsgLifetime* or *GetMsgLifetime*

Responses

- For example, join response

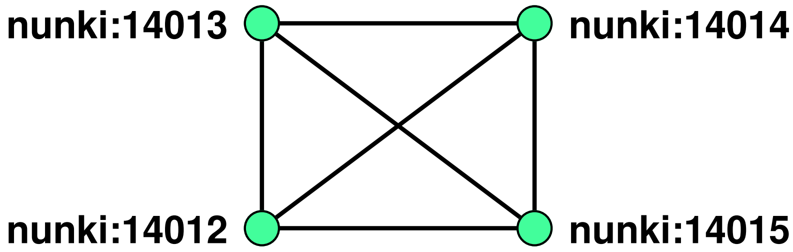


- Do not know exactly *who* initiated the join (only know the UOID of the join request)
  - use the UOID of the join request to do *routing*
  - intermediate nodes must *cache* a copy of the join request message and which link it came from in order to send the join response
  - join request initiator uses *JoinTimeout*

Network Formation

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



●	beacon node
●	regular node
—	neighbors
- - -	temporary connection

- beacon nodes are fully connected

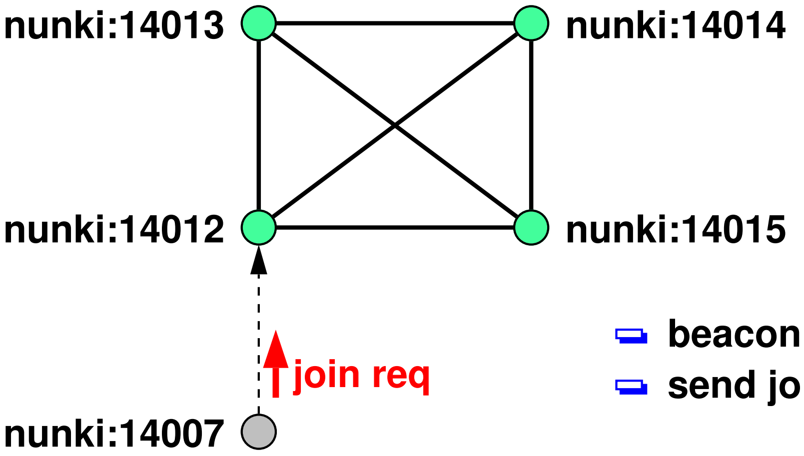
Join

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

startup-14007.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



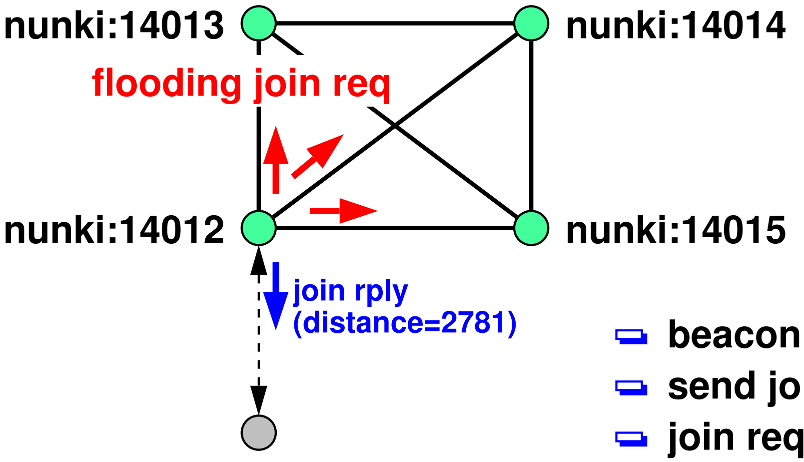
🟢 beacon node
⚪ regular node
— neighbors
- - - temporary connection

- beacon nodes are fully connected
- send join request to a beacon

Join

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



🟢 beacon node
⚪ regular node
— neighbors
- - - temporary connection

startup-14007.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

- beacon nodes are fully connected
- send join request to a beacon
- join request is flooded to the whole network, send join reply

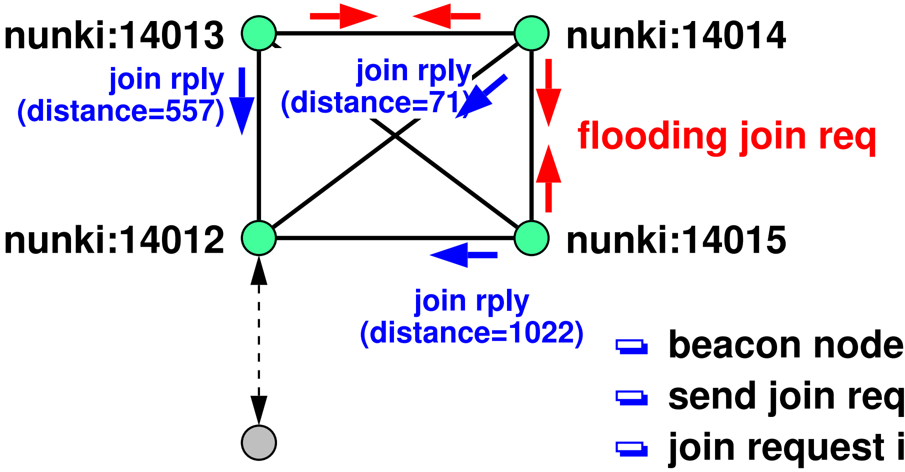
Join

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

startup-14007.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



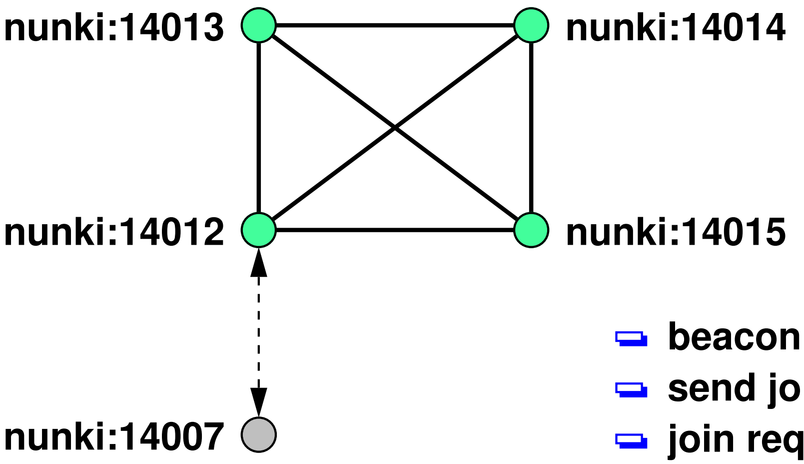
🟢 beacon node
⚪ regular node
— neighbors
- - - temporary connection

- beacon nodes are fully connected
- send join request to a beacon
- join request is flooded to the whole network, send join reply
- flooding stopped if packet already seen

Join

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



- ● beacon node
- ● regular node
- — neighbors
- - - - temporary connection

- beacon nodes are fully connected
- send join request to a beacon
- join request is flooded to the whole network, send join reply
- flooding stopped if packet already seen
- sort replies, write bottom ones to init_neighbor_list in HomeDirectory

startup-14007.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

nunki:14012 (2781)
nunki:14015 (1022)
nunki:14013 (557)
nunki:14014 (71)

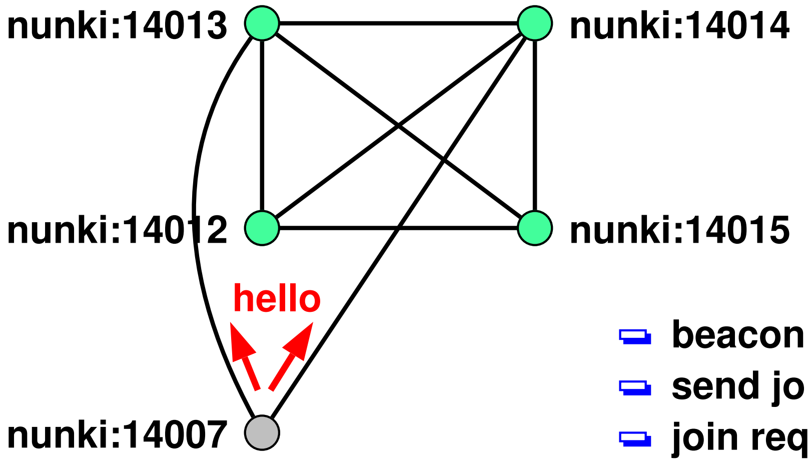
init_neighbor_list

```
nunki:14013
nunki:14014
```

Hello

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



startup-14007.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

init_neighbor_list

```
nunki:14013
nunki:14014
```

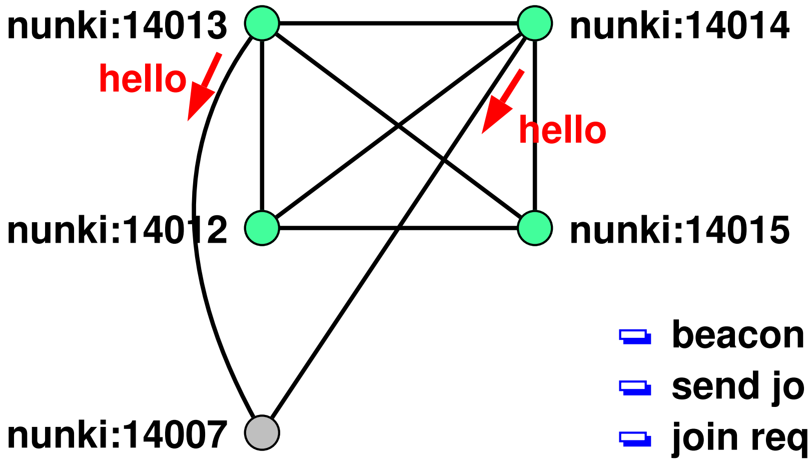
- ● beacon node
- ● regular node
- — neighbors
- - - - temporary connection

- beacon nodes are fully connected
- send join request to a beacon
- join request is flooded to the whole network, send join reply
- flooding stopped if packet already seen
- sort replies, write bottom ones to init_neighbor_list in HomeDirectory
- restart, no need to *join*, just say hello

Hello

startup-14012.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```



- ● beacon node
- ● regular node
- — neighbors
- - - - temporary connection

startup-14007.ini

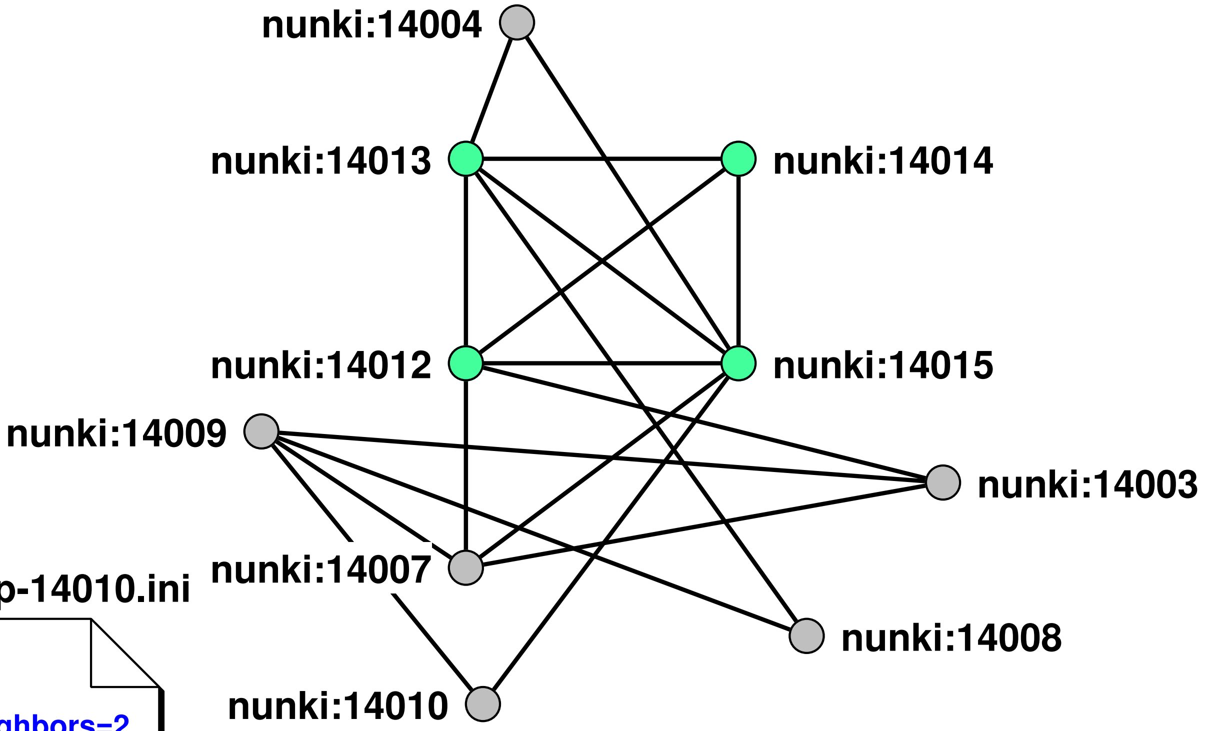
```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

init_neighbor_list

```
nunki:14013
nunki:14014
```

- beacon nodes are fully connected
- send join request to a beacon
- join request is flooded to the whole network, send join reply
- flooding stopped if packet already seen
- sort replies, write bottom ones to init_neighbor_list in HomeDirectory
- restart, no need to *join*, just say hello
- say hello back

SERVANT Network



startup-14010.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

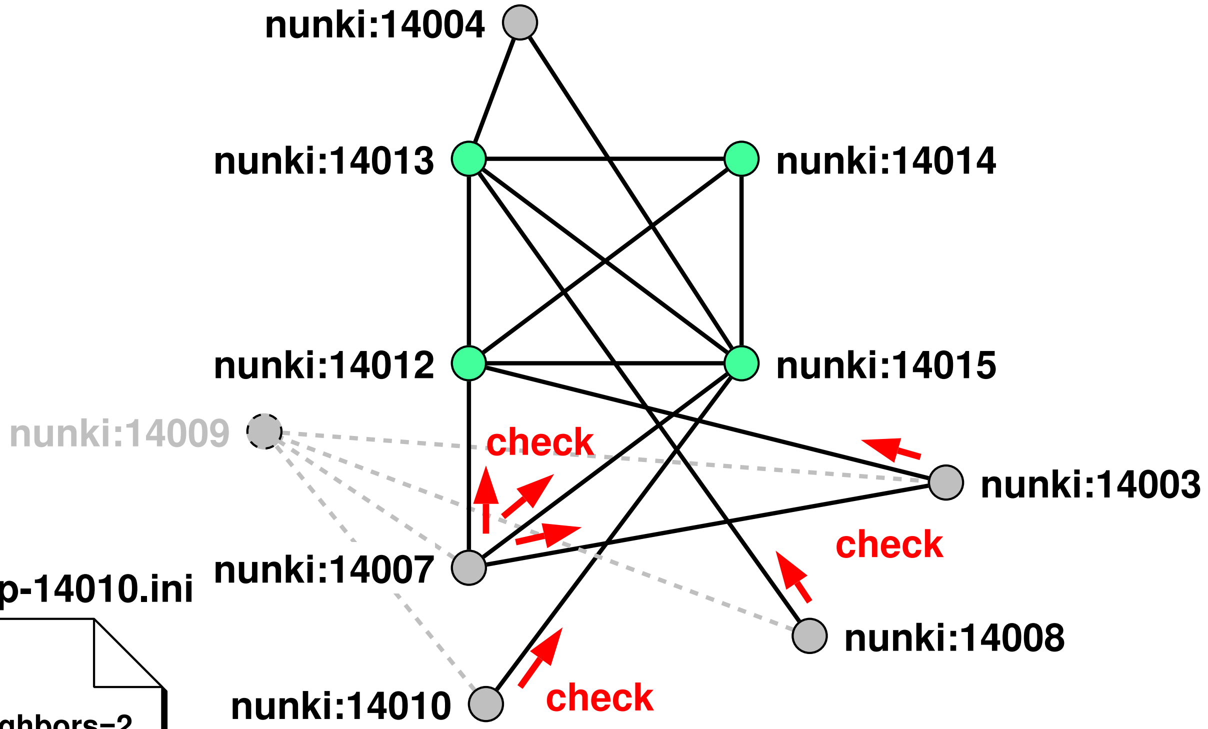
init_neighbor_list

```
nunki:14009
nunki:14015
```

startup-14003.ini

```
[init]
InitNeighbors=3
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

Node Goes Down



startup-14003.ini

```
[init]
InitNeighbors=3
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

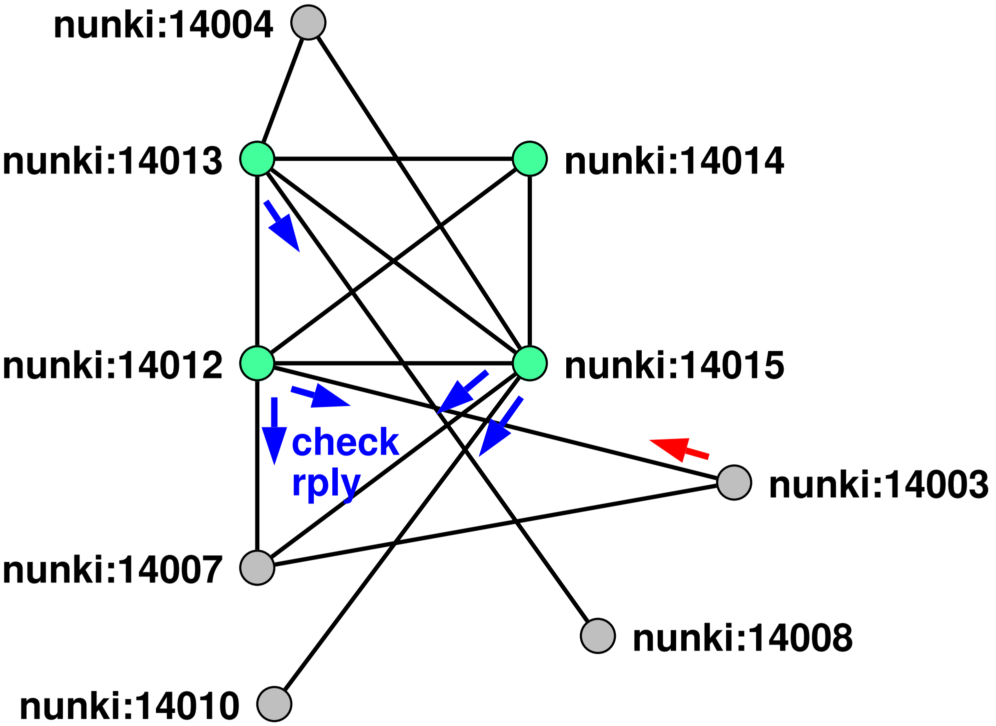
startup-14010.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

init_neighbor_list

```
nunki:14009
nunki:14015
```

Node Goes Down (Cont...)



startup-14003.ini

```
[init]
InitNeighbors=3
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

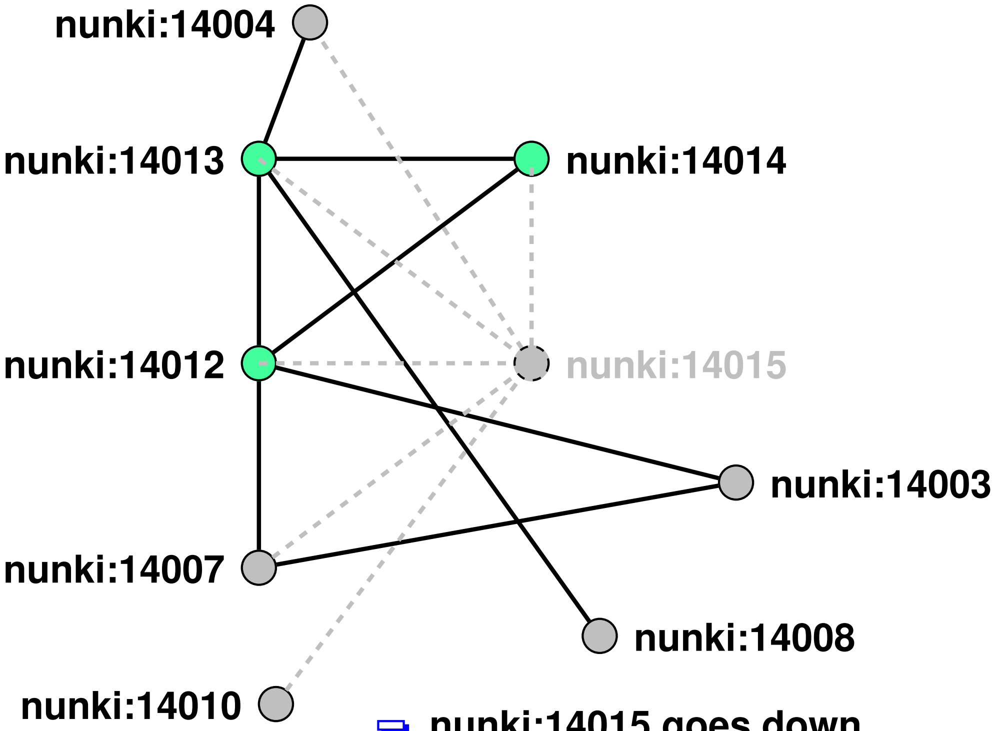
startup-14010.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

init_neighbor_list

```
nunki:14009
nunki:14015
```

Node Goes Down (Cont...)



startup-14003.ini

```
[init]
InitNeighbors=3
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

startup-14010.ini

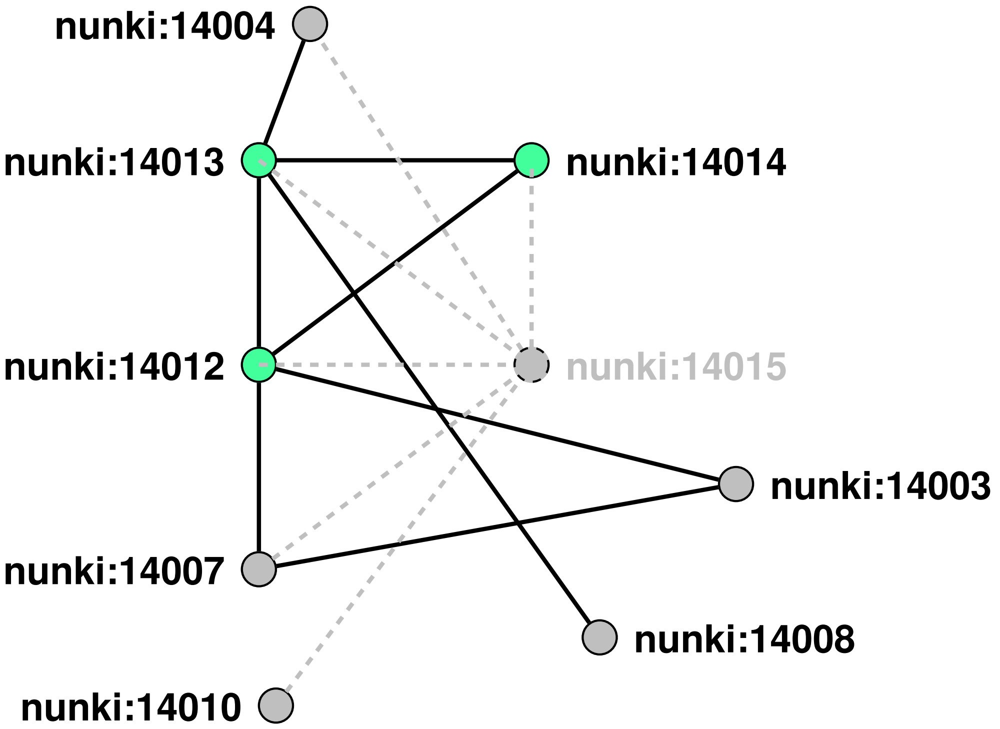
```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

init_neighbor_list

```
nunki:14009
nunki:14015
```

- nunki:14015 goes down
- network is partitioned,
  nunki:14010 will not get any check response messages (even if there are nodes connected to it from below)

Node Goes Down (Cont...)



startup-14003.ini

```
[init]
InitNeighbors=3
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

startup-14010.ini

```
[init]
InitNeighbors=2
MinNeighbors=1

[beacons]
nunki:14012=
nunki:14013=
nunki:14014=
nunki:14015=
```

~~**init_neighbor_list**~~

```
~~nunki:14009
nunki:14015~~
```

- nunki:14010 must *delete* its init_neighbor_list file
- nunki:14010 must *join* the network (start from scratch), it will reappear somewhere else in the network

Node Startup Configuration File

- **Ex:** `start-14014.ini`

```
[init]
Port=14014
Location=4294967295
HomeDir=/YOURHOME/servant/14014
LogFilename=servant.log
AutoShutdown=60
TTL=255
MsgLifetime=60
GetMsgLifetime=600
InitNeighbors=3
JoinTimeout=5
KeepAliveTimeout=7
MinNeighbors=2
NoCheck=0
CacheProb=0.1
StoreProb=0.1
NeighborStoreProb=0.1
CacheSize=1000

[beacons]
Retry=15
foo.usc.edu:12311=
foo.usc.edu:12312=
foo.usc.edu:12313=
foo.usc.edu:12314=
```

- ***Port*** is the well-known port that this node listens to
- the black keys in the `[init]` section are optional
  - check the spec for their default values

Node Startup Configuration File (Cont...)

- Don’t complain it takes too much effort to parse the file!!
  - suggestion: utility file (for the rest of your grad school)
    - *char *GetALine(FILE*):* read an *arbitrary* long line
      - use malloc() and realloc()
    - *void TrimBlanks(char*):* get rid of *leading* and *trailing* space and tab characters
    - *int GetKeyValue(char *buf, char separator, char **ppsz_key, char **ppsz_value):* get key and value from an input buffer

```
char *psz_value=strchr(buf, separator);

if (psz_value == NULL) return ERR_CANNOT_FIND_SEPARATOR;
*psz_value++ = '\0';
TrimBlanks(buf);
TrimBlanks(psz_value);
if (ppsz_key != NULL) *ppsz_key = buf;
if (ppsz_value != NULL) *ppsz_value = psz_value;
```

Node Startup Configuration File (Cont...)

Table driven

```
typedef struct tagKwInfo {
  int id;
  char *key;
  /* what else? */
} KwInfo;

#define KW_PORT 1001
#define KW_HOMEDIR 1002
...
#define KW_PERMSIZE 10xx

static KwInfo gkwinfo[] = {
  { KW_PORT, "port" },
  { KW_HOMEDIR, "homedir" },
  ...
  { KW_PERMSIZE, "permsize" },
  { INVALID, NULL }
};
```

```
char *psz_key=NULL, *psz_value=NULL;

if (GetKeyValue(line, ’=’, &psz_key,
    &psz_value) == 0) {
  KwInfo *pwi=gkwinfo;
  int found_id=(-1);

  for (;;pwi++) {
    if (pwi->key == NULL) break;
    if (strncasecmp(pwi->key,
        psz_key) == 0) {
      found_id = pwi->id;
      break;
    }
  }
  if (found_id == (-1)) {
    return ERR_UNRECOGNIZED_KEY;
  }
  switch (found_id) {
  case KW_PORT: ...
  case KW_HOMEDIR: ...
  }
}
```

Data Structures

- List
  - from warmup #2
- Efficient data structure
  - Binary Search Tree (BST)
    - you can use `libavl` if you don't have something you already like
    - not required
  - Bloom Filter
    - required
    - for part (2), you don't have to worry about it for now

How to Manage Timers

- Networking programming often requires you to manage many timers
  - e.g., MsgLifetime
    - you need to implement a messge cache, keyed on UOID
      - drop duplicate messages
      - route response messages
    - every time you cache a message, conceptually, you should start a timer
    - when the timer expires, you can remove the message from your message cache data structure
    - need to cache a message for quite a long time
      - you can end up with thousands of timer
  - e.g., KeepAliveTimeout
    - not as many timers, but you need to keep track of them

How to Manage Timers (Cont...)

- Solution: have a timer that goes off every second
  - for all the timeouts that are specified as multiple of seconds
    - if a timer suppose to go off in 9 seconds, does it matter if it goes off 9.7 seconds later?
  - if a timeout is suppose to be for 15 seconds, initialize a count of 15
    - every time the timer goes off, *scrub* all timer-related data structures
    - if a count reaches zero, delete the object from the data structure
  - you can use a timer thread for this
  - if you have events that needs to be timed-out in resolution of multiple hundreds of milliseconds, use another timer that goes off every 100 millisecond

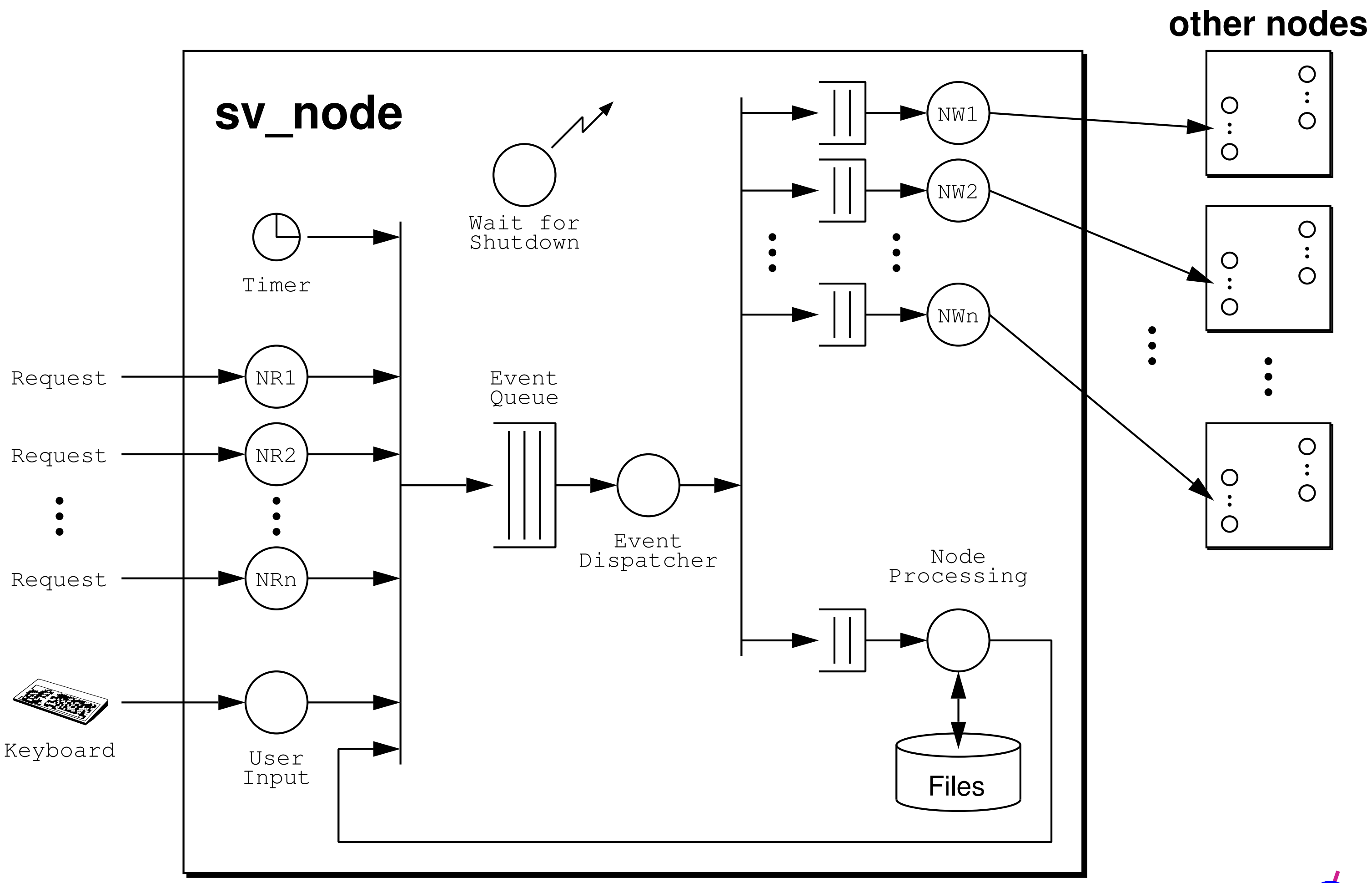
Soft Restart

Here is a simple way to implement soft restart:

```
int main(int argc, char *argv[])
{
  gnShutdown = FALSE;
  while (!gnShutdown) {
    Init();
    Process();
    CleanUp();
  }
  return 0;
}
```

- only set `gnShutdown` to TRUE if you want the program to exit (such as when the autoshutdown timer goes off)
  - otherwise, you are doing a *soft restart*
- in `CleanUp()`, you can clean up everything
  - kill all threads, free up all memory, reset all variables (except `gnShutdown`)
- keep the *state* of your program in your node's HomeDir

A Design, Just A Design



A Design, Just A Design (Cont...)

- Event-driven style
- Identify all your threads
  - draw them as circles
  - on the previous slide, there are 2 threads to handle communication with a neighboring node
    - this is not the only way, you need to decide what you are most comfortable with
- Identify all your shared data structures
  - draw them as queues
  - use shared data structures for thread-to-thread communication and thread synchronization
  - protect each shared data strcuture with a mutex
  - there may be other shared data structures that needs to be protected by mutexes, e.g., logfile

Keep Track of Neighbors

- How do you keep track of neighbors so you can look it up?
  - For example, if you get a message from a neighbor and want to forward it to all other neighbors
    - should you use socket descriptor number to distinguish different neighbors?
      - probably not a good idea
      - socket descriptors get reused as you lose and gain connections
    - should you use hostname and port numbers?
      - may not be a good idea
      - neighbors go up and down

Keep Track of Neighbors (Cont...)

- Solution: use a connection data structure/object
  - Each "connection" has a unique numeric ID
    - monotonically increase it when you need a new ID
  - Store neighbor hostname and port numbers in it
  - Store socket descriptors in it
  - Write a bunch of utility functions/methods for it
- When you want to refer to something related to a neighbor, have it refer to a connection object
  - For a network-read thread, have it reference a "connection" (or a connection ID)
  - For a message in the message cache, have it reference a connection number
- Hopefully, this can remove some ambiguities