Wireless Sensor Network Security in ProFuN

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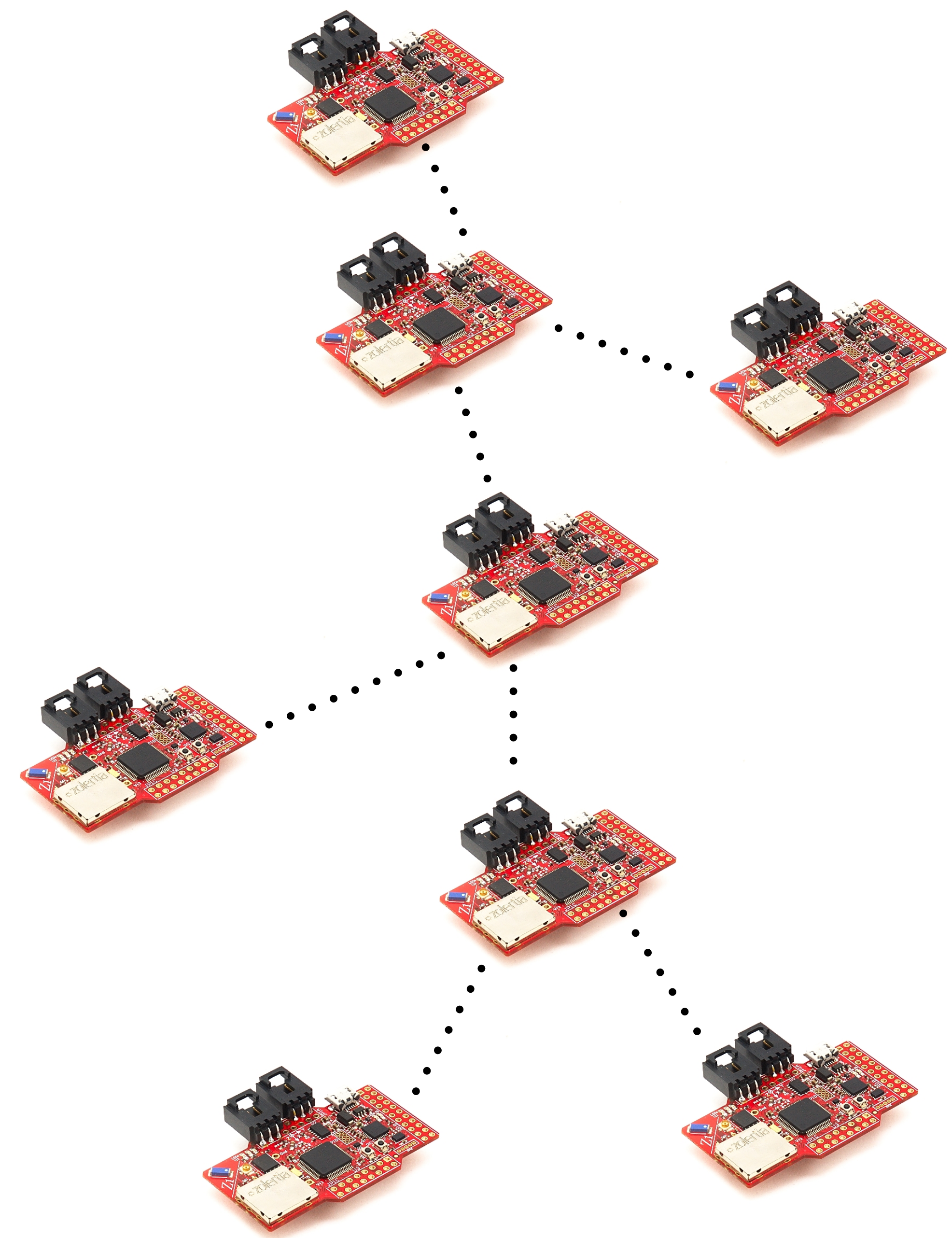
Wireless Sensor Networks

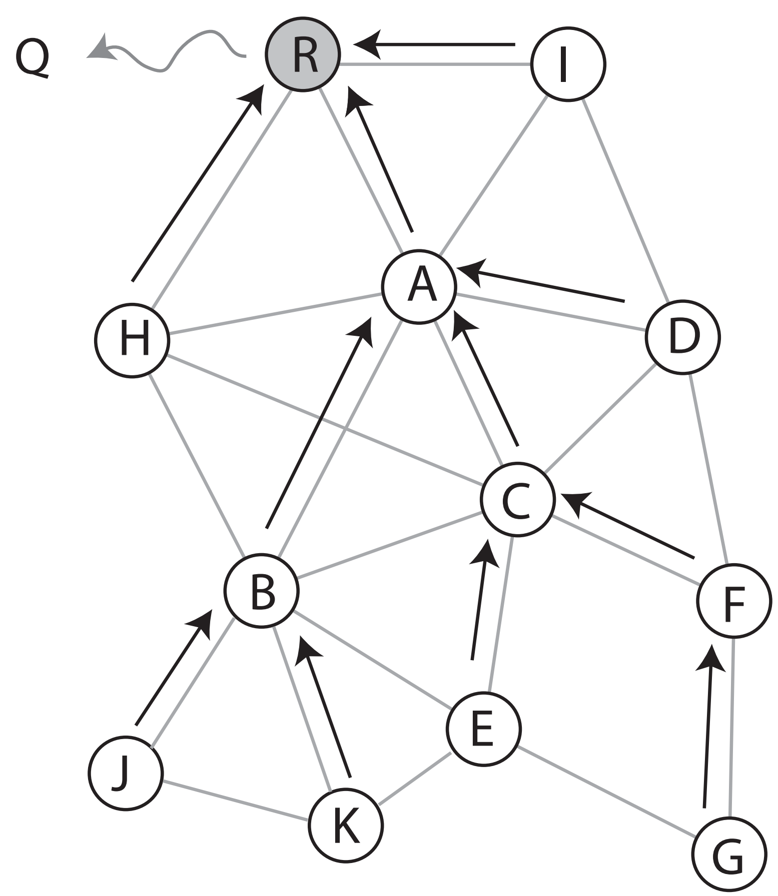
1. Formal verification of a secure aggregation protocol

2. Trust establishment for secure communication in the demonstrator



Secure Hierarchical In-Network Aggregation in Sensor Networks

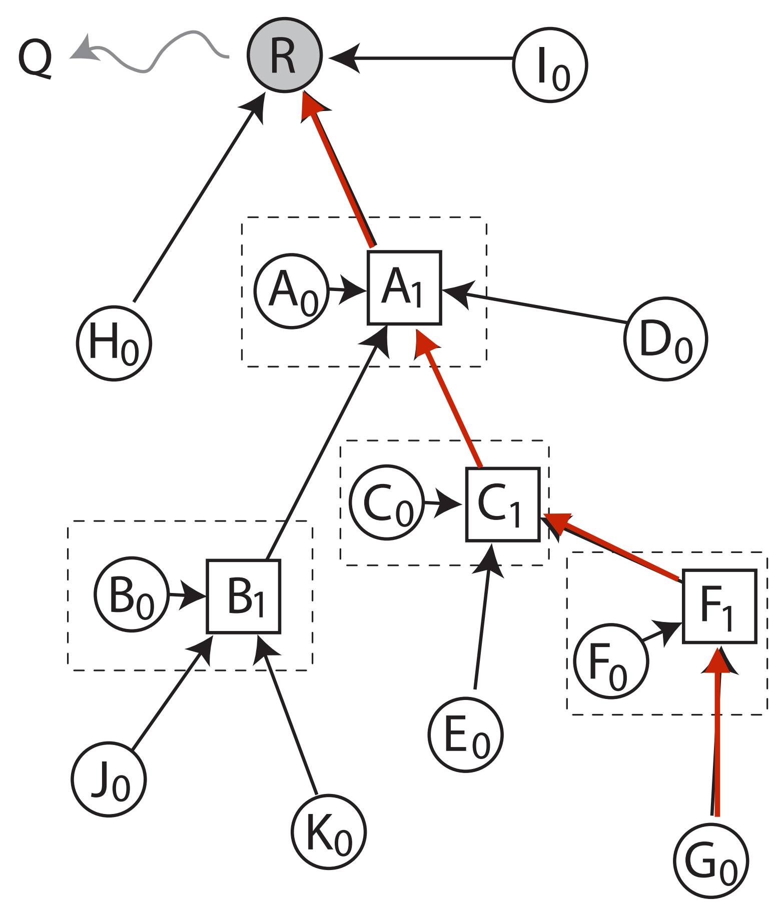
Spanning tree



Secure Hierarchical In-Network Aggregation in Sensor Networks

Aggregation

Label = <count, value, complement, hash-value>



$$R = \langle 12, v_R, \bar{v}_R, H[N||12||v_R||\bar{v}_R||H_0||A_1||I_0]\rangle$$

$$A_1 = \langle 9, v_{A_1}, \bar{v}_{A_1}, H[N||9||v_{A_1}||\bar{v}_{A_1}||A_0||B_1||C_1||D_0]\rangle$$

$$C_1 = \langle 4, v_{C_1}, \bar{v}_{C_1}, H[N||4||v_{C_1}||\bar{v}_{C_1}||C_0||E_0||F_1]\rangle$$

$$F_1 = \langle 2, v_{F_1}, \bar{v}_{F_1}, H[N||2||v_{F_1}||\bar{v}_{F_1}||F_0||G_0]\rangle$$

$$G_0 = \langle 1, a_G, r - a_G, G\rangle$$

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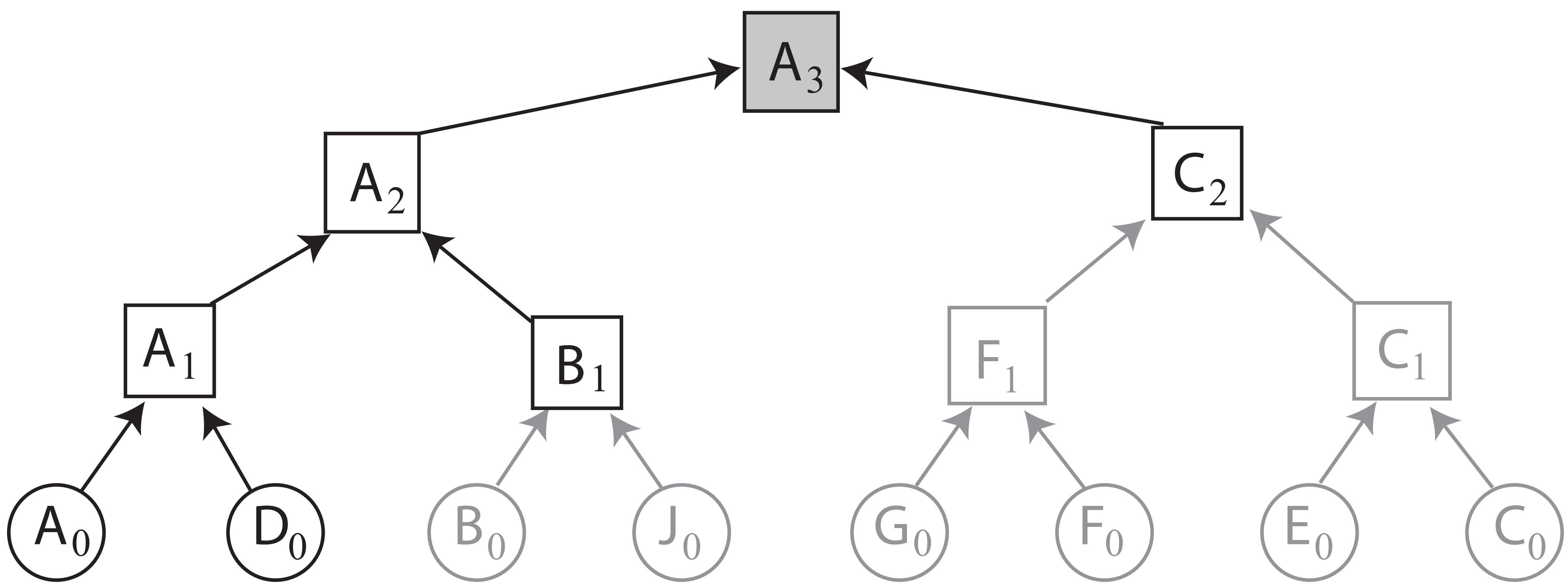

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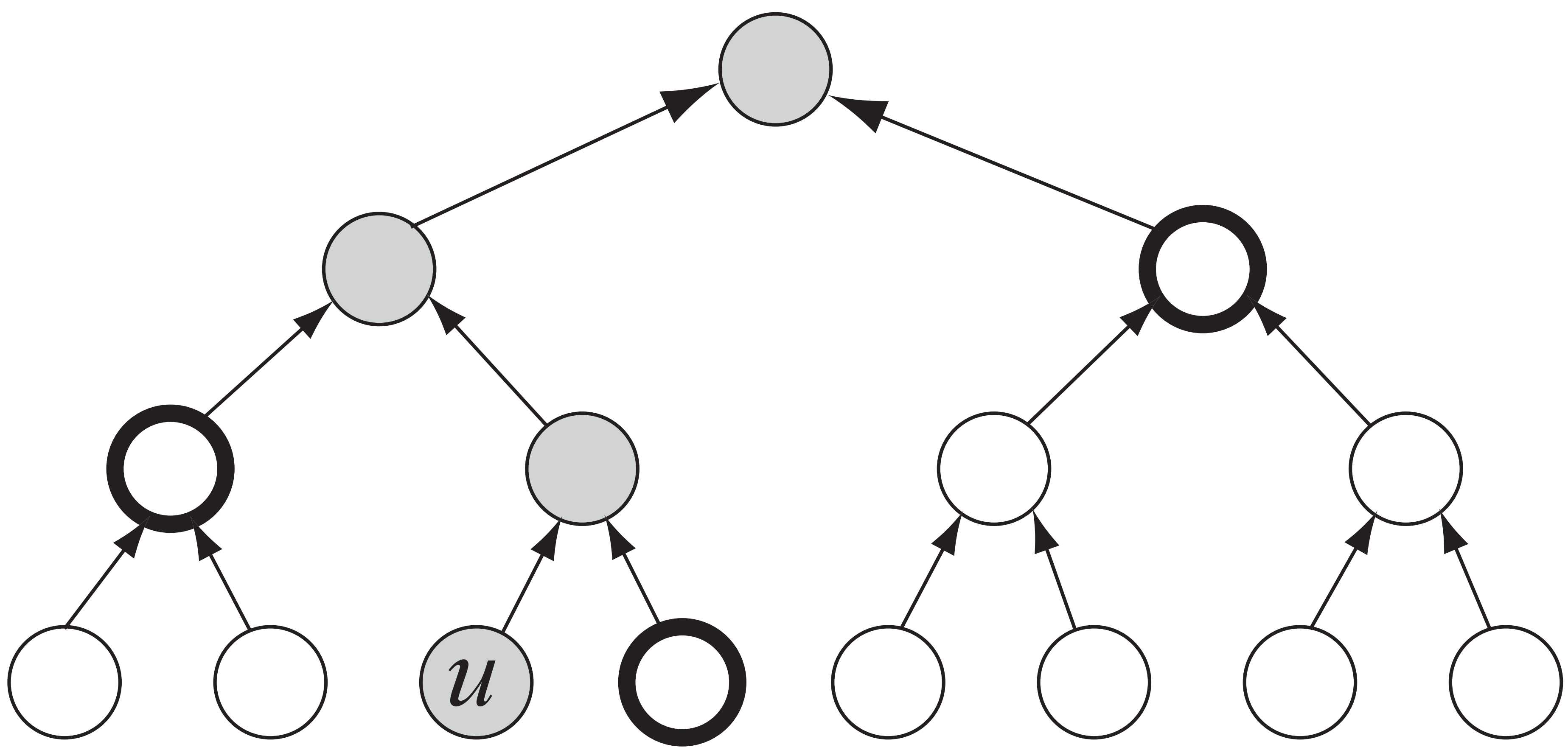

Off-path vertices of u

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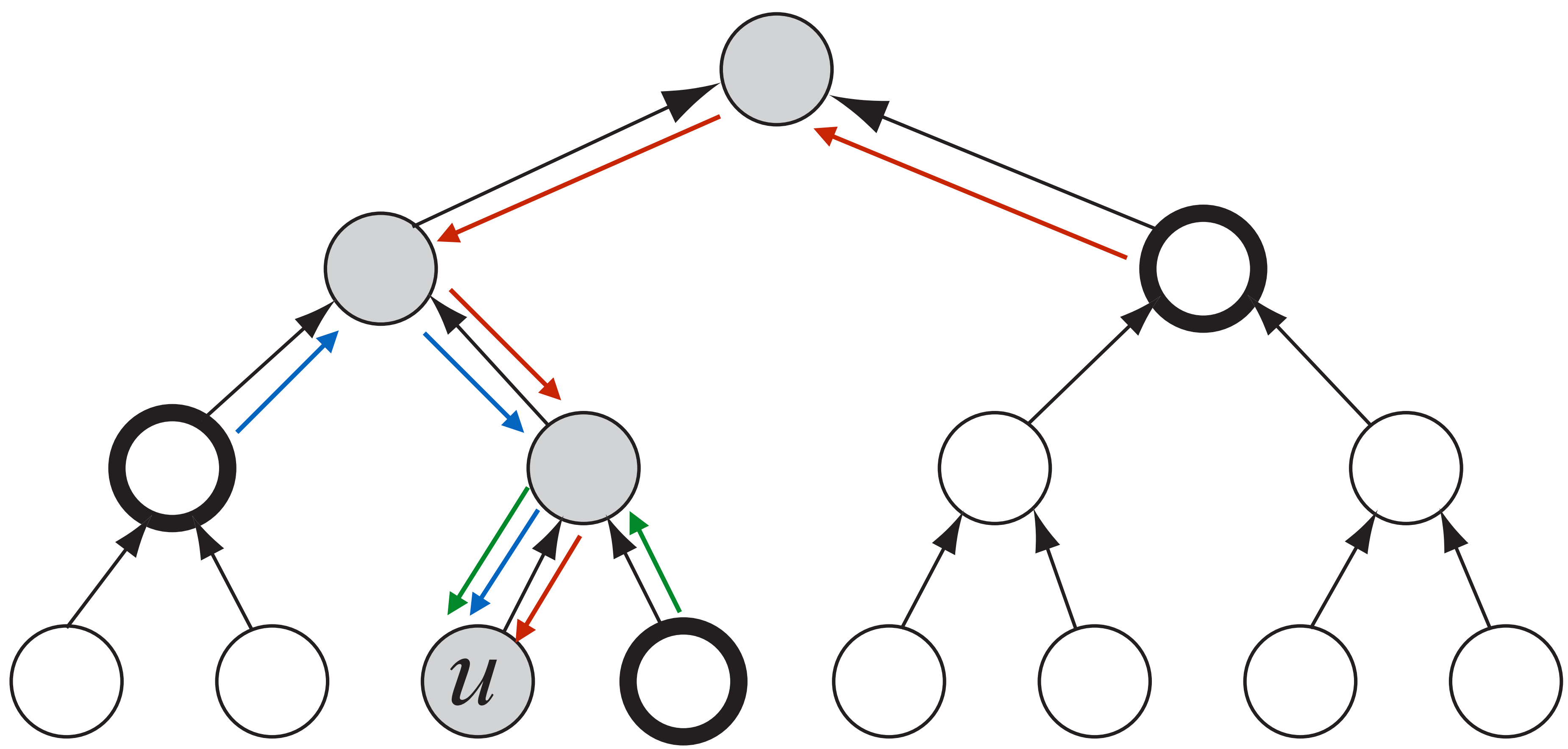
Authentication



MAC$_{Ku}$(Nonce,OK)

The Goal

Formally verify that the security property of SHIA indeed holds

Definition 1 *A **direct data injection** attack occurs when an attacker modifies the data readings reported by the nodes under its direct control, under the constraint that only legal readings in* $[0, r]$ *are reported.*

Definition 2 *An aggregation algorithm is **optimally secure** if, by tampering with the aggregation process, an adversary is unable to induce the querier to accept any aggregation result which is not already achievable by direct data injection.*

Progress

1. Extract the algorithm from the paper
2. Take the algorithm to Psi-calculus specification
    - Focus on process communication
    - Abstract away from the details (helper functions and computations)
3. Define the **terms**, the **conditions** and the **assertions**
    - Revise several times to simplify
4. Write the rules for parsing and printing the specification

Some examples

Terms

```
val sgnSpecification =
    " Sorts                                                    " ^
    "                                                          " ^
    " ch, tch,                                                 " ^
    " i,                                                       " ^
    " nonce, key, hash, mac,                                   " ^
    " lbl, llist,                                              " ^
    " dir                                                      " ^
    "                                                          " ^
```

Conditions

```
" LT : (i,i) => bool,                " ^
" and : (bool,bool) => bool,         " ^
" not : (bool) => bool,              " ^
" iEq : (i,i) => bool,               " ^
" dEq : (dir,dir) => bool            " ^
```

Other functions

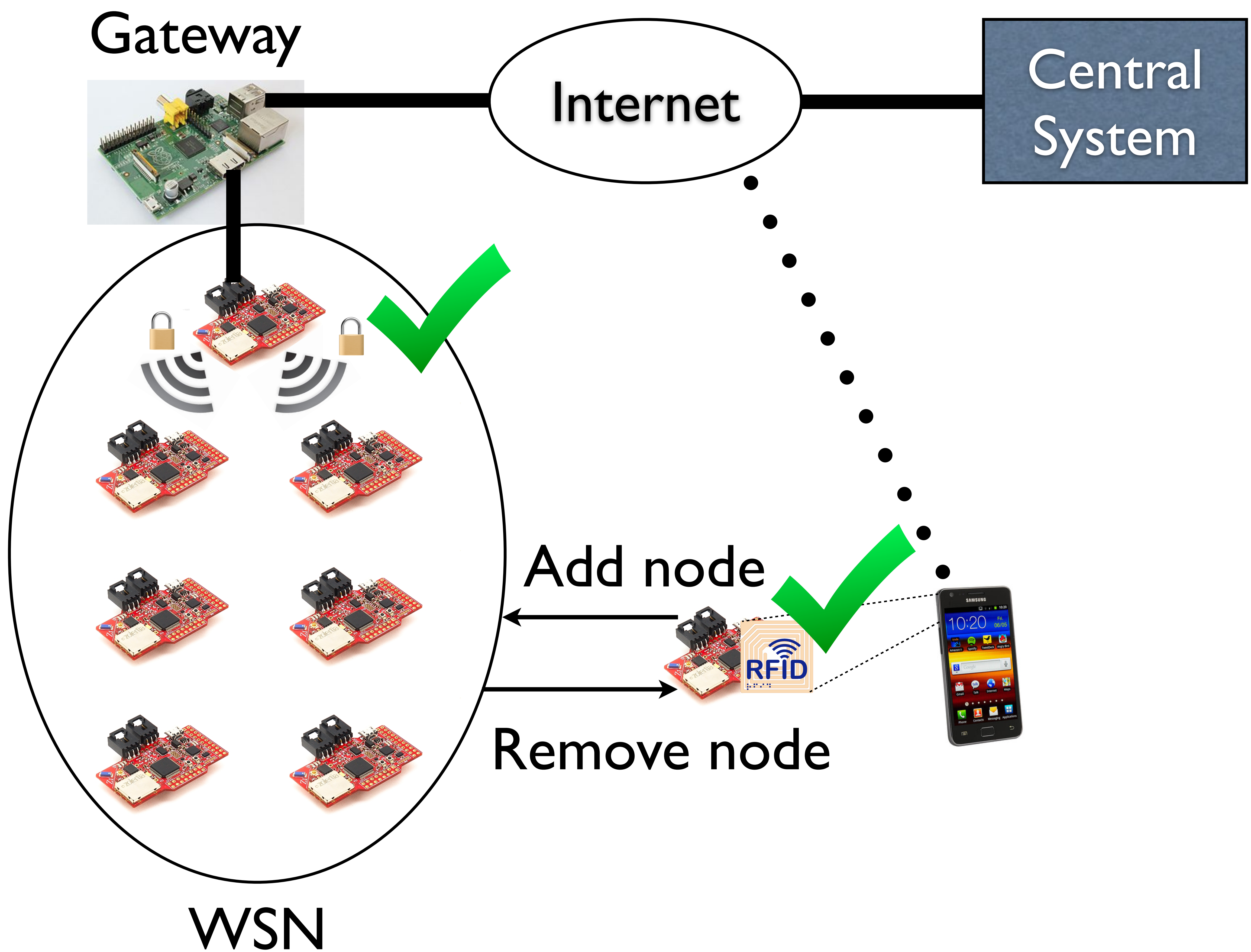
```
" XOR : (mac,mac) => mac,            " ^
" Log2 : (i) => i,                   " ^
" Dec : (i) => i,                    " ^
" Add : (i,i) => i,                  " ^
" Sub : (i,i) => i,                  " ^
" Sort : (llist) => llist,           " ^
" dLeft : () => dir,                 " ^
" dRight : () => dir,                " ^
```

Some examples

```
NodeVerify(chParent, chLeft, chRight, chFail, iMinVal, nonceQ, iKey,
           iLeftID, iRightID,
           iCountLeft, iValLeft, iCompLeft, hashLeft,
           iCountRight, iValRight, iCompRight, hashRight,
           iCountInHere,
           iCountOwn, iValOwn, iCompOwn, hashOwn) <=
    "Verify(chParent)"(iCountRoot, iValRoot, iCompRoot, hashRoot).
    case "not(and(iEq(iLeftID, 0), iEq(iRightID, 0)))" :
        '"Verify(chLeft)"<iCountRoot, iValRoot, iCompRoot, hashRoot>.
        '"Verify(chRight)"<iCountRoot, iValRoot, iCompRoot, hashRoot>.
        '"Offpath(chLeft)"<iCountRight, iValRight, iCompRight, hashRight, "dRight()">.
        '"Offpath(chRight)"<iCountLeft, iValLeft, iCompLeft, hashLeft, "dLeft()">.
        ForwardOffpathLabels<chParent, chLeft, chRight, nonceQ, iKey,
                             iLeftID, iRightID, "Sub(Log2(iCountRoot), Log2(iCountInHere))">
    [] "and(iEq(iLeftID, 0), iEq(iRightID, 0))" :
        ReceiveOffpathLabels<chParent, chLeft, chRight, chFail,
                             iMinVal, nonceQ, iKey, iLeftID, iRightID,
                             iCountOwn, iValOwn, iCompOwn, hashOwn,
                             iCountRoot, iValRoot, iCompRoot, hashRoot,
                             "Log2(iCountRoot)", "LNil()">;
```

Next step

1. Implement abstracted details (helper functions and computations)
2. Implement constraint solver to handle the specification
    1. the properties that we need to check
        1. off-path labels
        2. boundaries


Gateway
Internet
Central System
Add node
RFID
Remove node
WSN

Encryption & Authentication

- Node: Zolertia Z1
- OS: Contiki
- Chip: CC2420 (2.4 GHz IEEE 802.15.4 Compliant and ZigBee™ Ready RF Transceiver)
- AES-CCM (Counter with CBC-MAC) 128 bits
    - Link layer software solution from Thingsquare Mist

Setting

1. Data Aggregation in a tree-based WSN
2. A node has to know at most 3 neighbours
   - Parent
   - Left child
   - Right child
3. **Problem: Securely introduce a new node to the aggregation tree as a**
   - **Leaf (sensing) node**
   - **Aggregating node**

Introduce a new node

1. Bring initialized node to the network. (known UID, net address and cryptographic keys)
2. Scan RFID/NFC tag with smartphone. (the tag has new node's UID)
3. Securely transmit the scanned value to the central system from the smartphone.
4. Central system validates the value and if it is valid, locate the associated network address in the network.

Introduce a new node

5. When the node receives message from the central system, it has instructions to update neighbour data.
6. The new node confirms that the neighbour data is applied
7. Central system sends update requests to affected neighbours
8. Central system collects replies from neighbour nodes that the update is done!

Introduce a new node

9. If successful, the role of the new node can be selected from the central system so that the necessary code is sent to the new node securely via the WSN.
10. Otherwise, the existing nodes neglect the new node.

Key Management

1. Base to node
2. Features:
    - Backward secrecy - new member should not be able to decrypt old messages.
    - Forward secrecy - old member should not be able to decrypt new messages.
    - Group re-keying - group keys have to be re-arranged so that previous two features are supported.

DEMO!

Next step

1. Implementing μTesla in Contiki
2. Dynamic addition of a new node and/or re-location of an existing node
3. Different key management techniques
   - asymmetric
   - zero-knowledge