Exploiting Resource Heterogeneity in Delay-Tolerant Networks using a Holistic Approach

Gabriel Sandulescu, Peter Schaffer and Simin Nadjm-Tehrani

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Resource-aware routing

- Resources for store-carry-forward schemes:
  - Buffer space
  - Energy
  - Bandwidth
    - # meetings
    - link duration

  Only 1 missing/inadequate resource = routing failure

- Resource heterogeneity:
  - Diversity of nodes
  - Non-uniform node density
  - Unbalanced injection points / delivery nodes

Motivation

Custodian election:

- How many custodians ?
- Which to choose ?
- Based on what criteria ?

Queue management:

- Which message to send ?
- In what order ?
- What message to delete ?

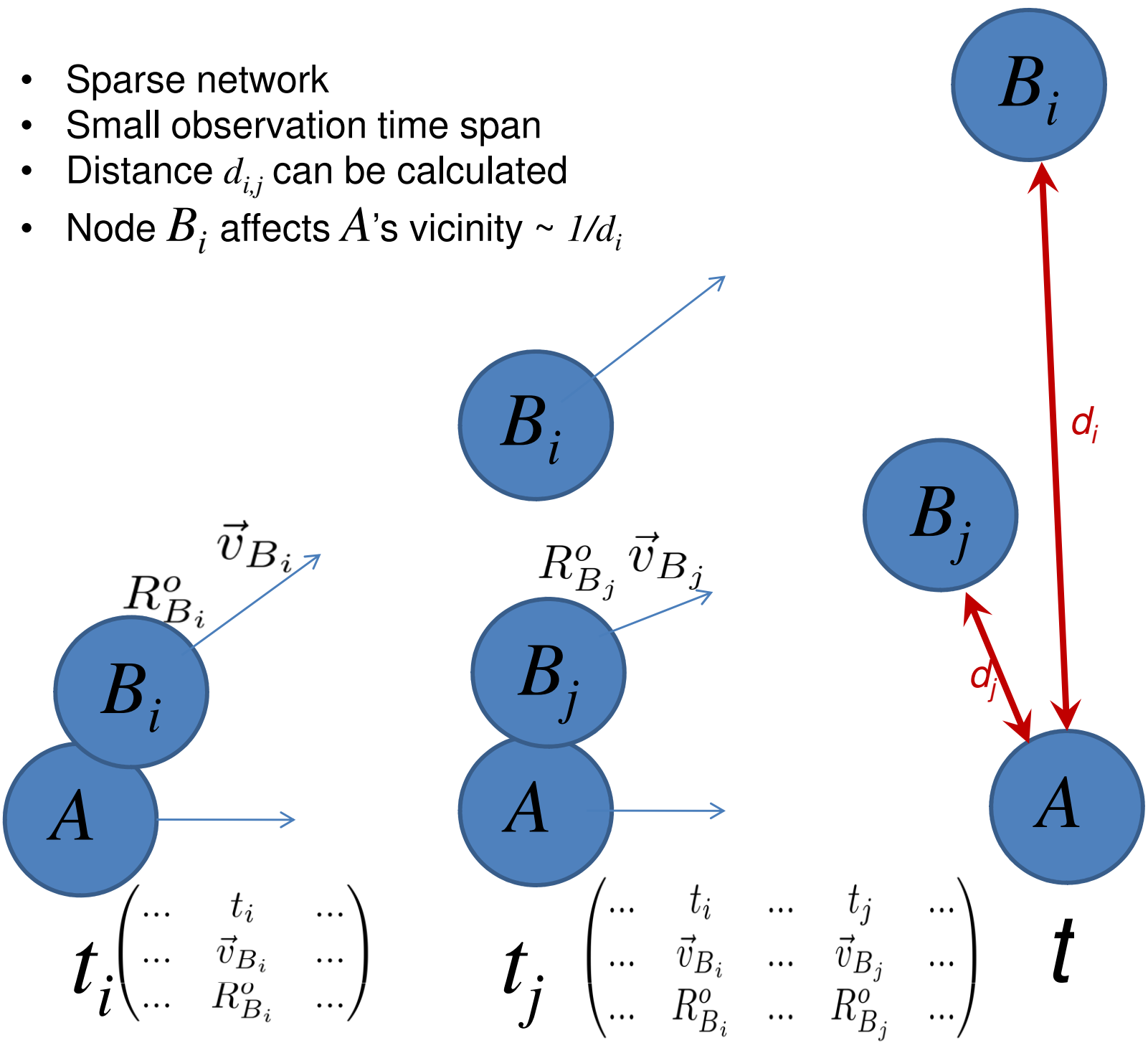
Might help…
if available resource could be estimated

Contributions

1. Approximate available resources:
   - in the vicinity
   - without prior knowledge, distributed scheme
   - orthogonally on routing
   - treating all 3 resources as a whole

2. Adaptive Queue Management and Custodian Election policies
   - minimising & control of resource usage
   - minimising resource variation in the node population: minimising # exhausted nodes

- Sparse network
- Small observation time span
- Distance $d_{i,j}$ can be calculated
- Node B_i affects A's vicinity ~ $1/d_i$



Estimated vicinity resources

Exchange between nodes:

$$I_i = (\vec{v}_i, R_i^o)$$

Store at each node:

$$\begin{pmatrix} t_i & t_{i+1} & \dots & t_j \\ \vec{v}_i & \vec{v}_{i+1} & \dots & \vec{v}_j \\ R_i^o & R_{i+1}^o & \dots & R_j^o \end{pmatrix}$$

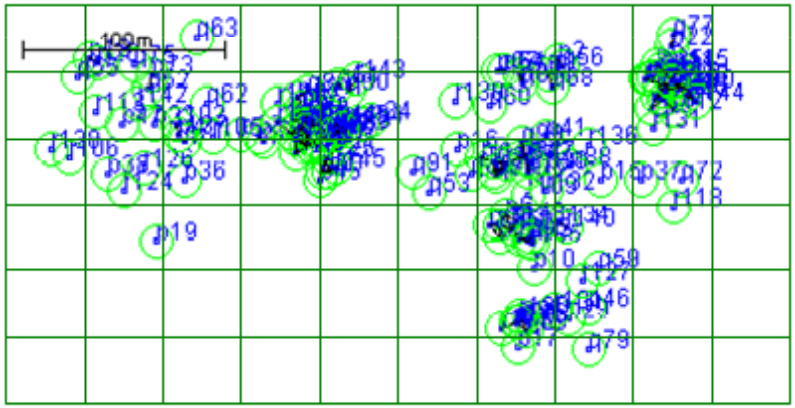
Estimated vicinity resources

$$R_A^v = \underbrace{\frac{n_\tau}{\omega \times \tau}}_{c_A} \times \underbrace{\frac{\sum_{k=i}^{j} \frac{R_k^o}{d_k}}{\sum_{k=i}^{j} \frac{1}{d_k}}}_{\overline{R}_A} \quad (1)$$

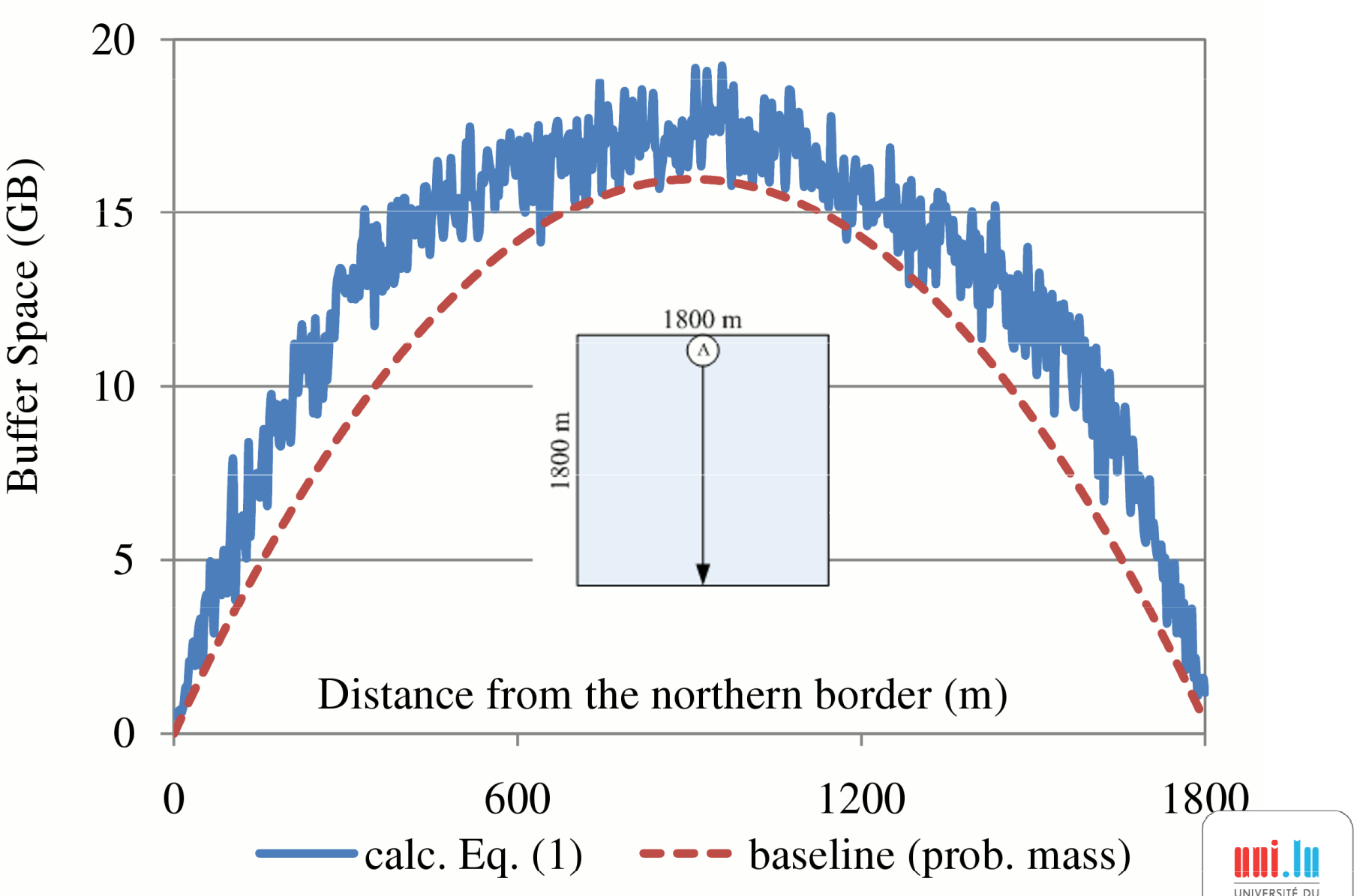
where: τ = observation time span
ω = node's average meeting frequency
n_τ = $j - i + 1$, number of nodes A actually met during observation time τ

Validation by simulation

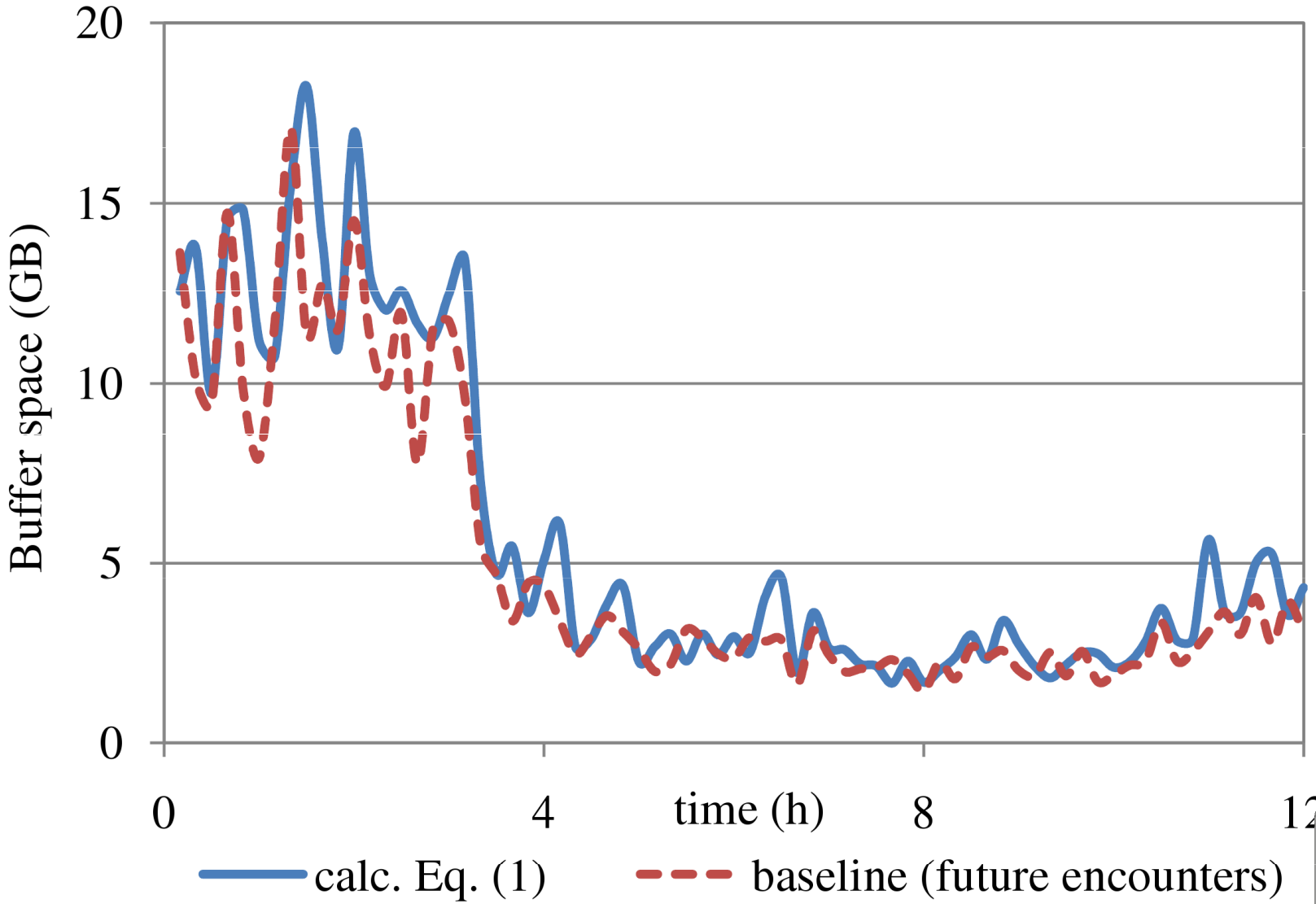
- 2 Mobility models:
  - random waypoint
  - Bonn motion (disaster area scenario)
- 3 Baselines:
  - theory (random waypoint)
  - future encounters
  - cell resources



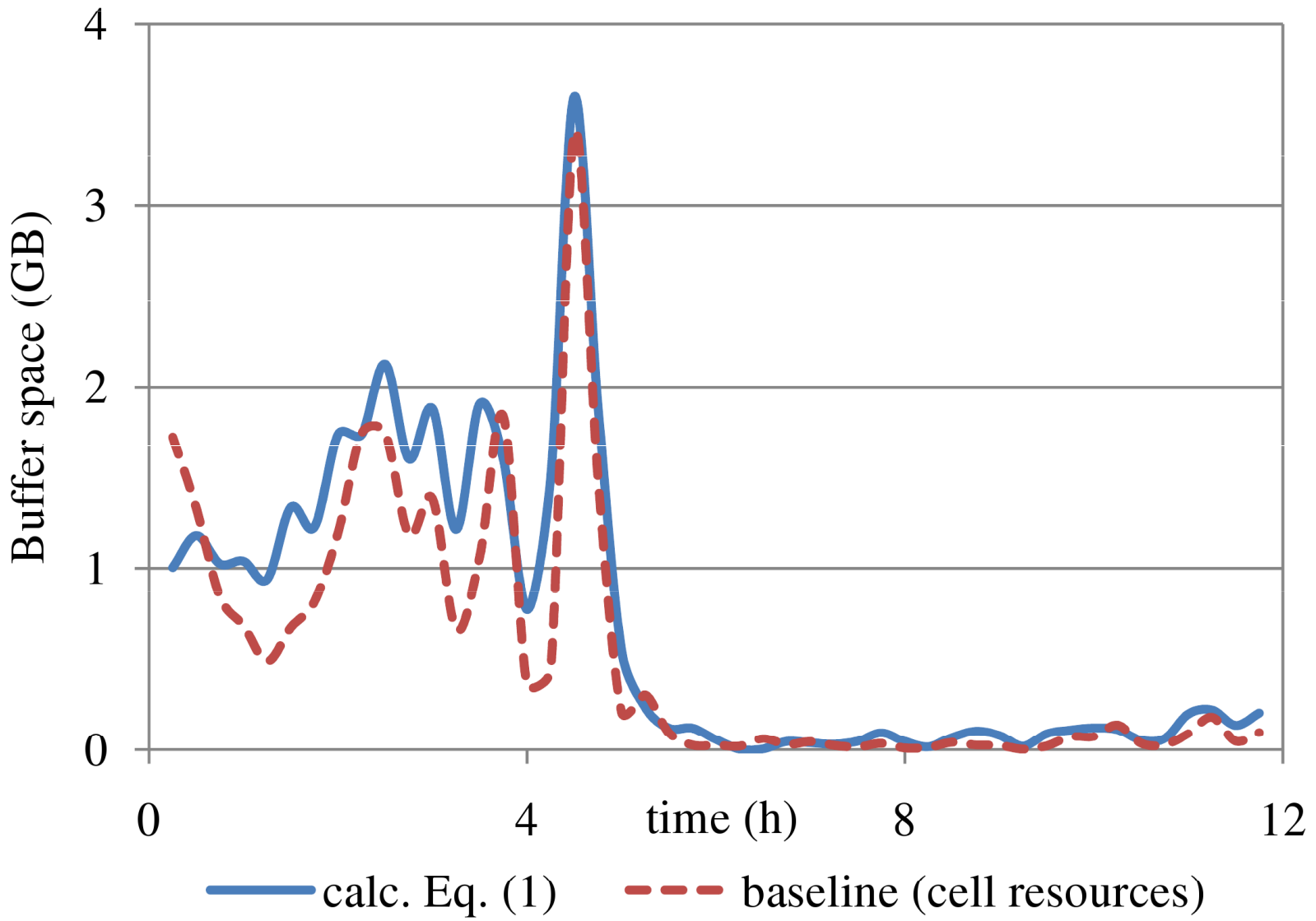
Validation: RWP, baseline: theory



Validation: future encounters

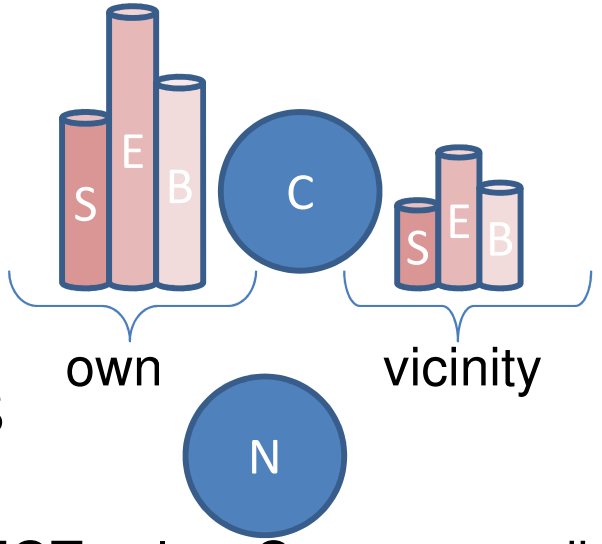


Validation: cell resources



CE + QM Policies (basic version)

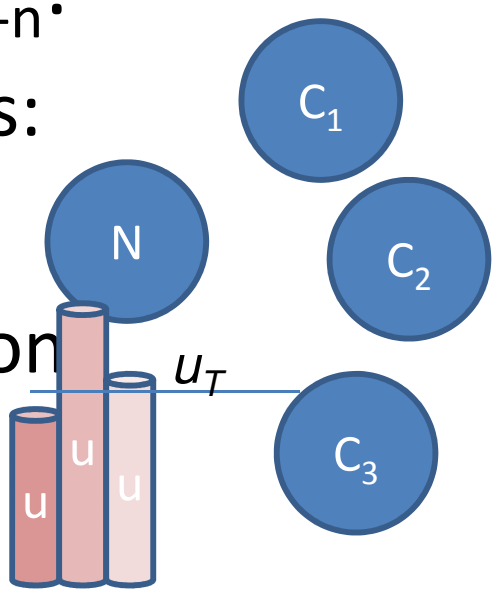
- Known at every encounter:
  - **node's own** available resources
  - **node vicinity** available resources
- Custodian election (CE):
  - select node ⇔ better opportunity than vicinity
- Queue management (QM):
  - select message ⇔ if resources allow it
  - if not, send a smaller message



CE - controlled version

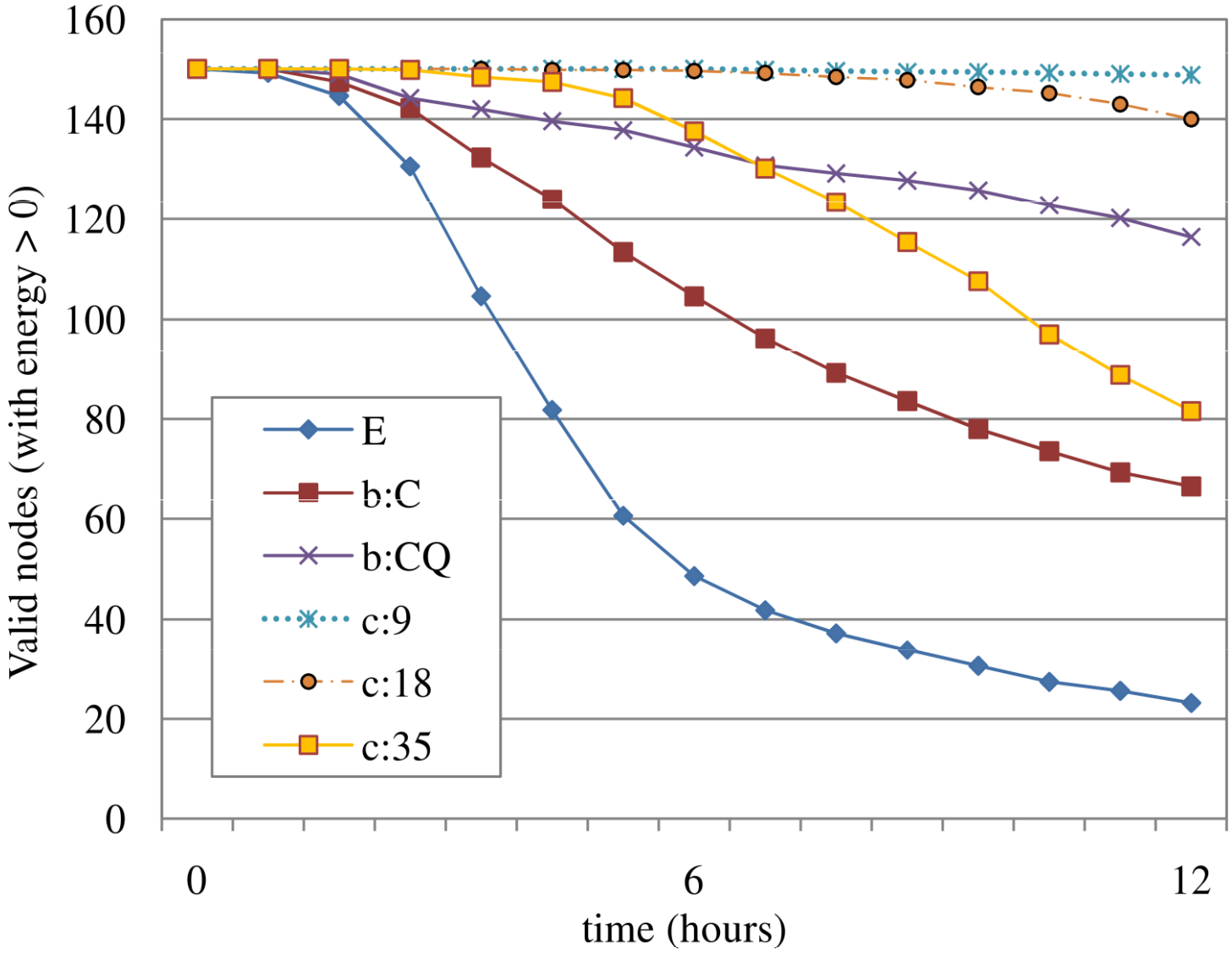
- Utility $u_{1\text{-}n}$ of choosing node $C_{1\text{-}n}$:
  - As a function of node's resources:

    u(energy, buffer, bandwidth)
  - Select u_T such that a given fraction of nodes are selected



- Benefits:
  - Control of the number of custodians
  - Taking only those with highest resource assets

Performance evaluation – valid nodes

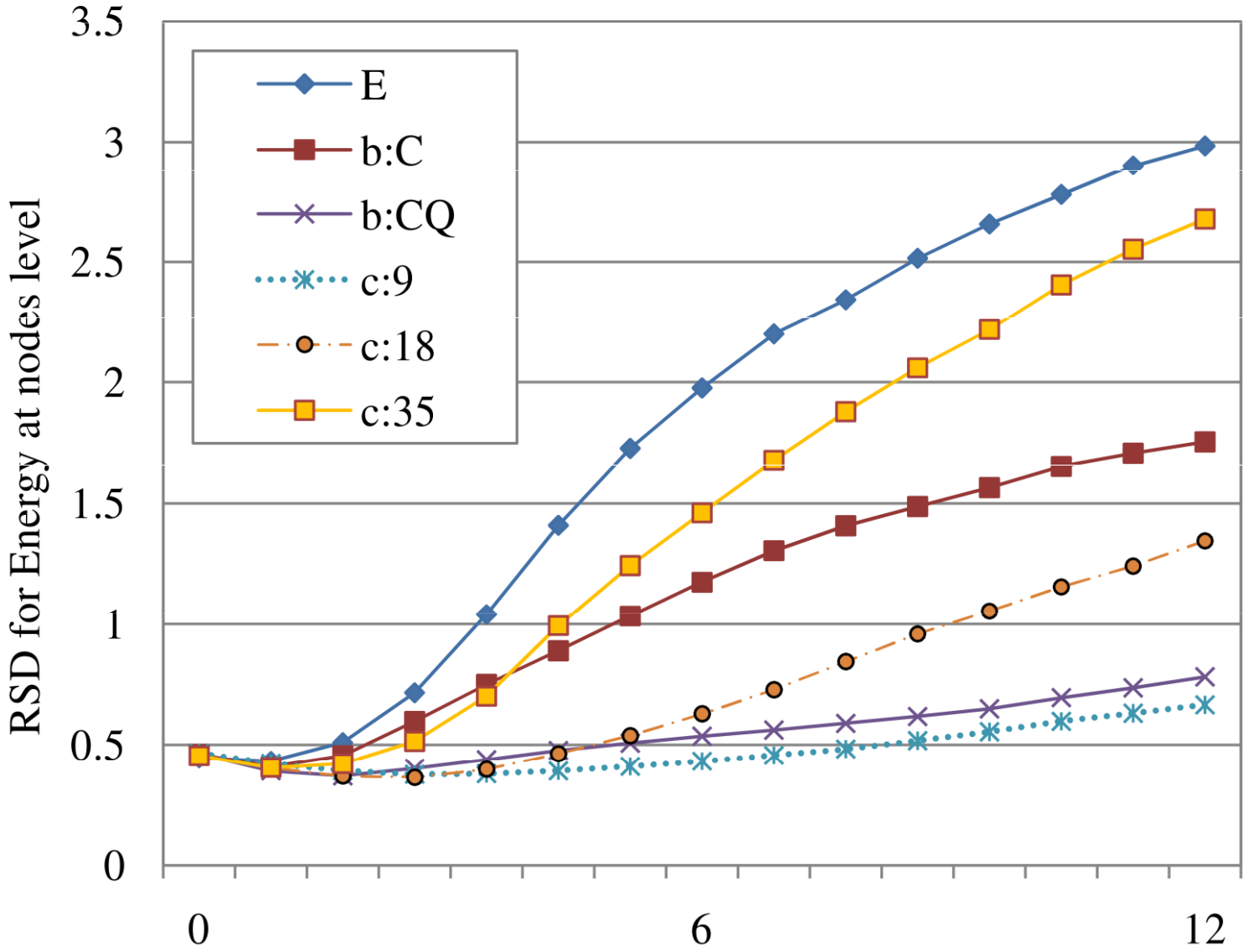


Performance evaluation coefficient of variation

$$CV_E = \frac{\sqrt{\frac{1}{N}\sum_{1}^{N}(E_i - \overline{E})^2}}{\overline{E}}$$

where: CV_E = coefficient of variation for energy
N = number of nodes (150 in our case)
E_i = energy of node i
$\overline{E}$ = energy mean value

Performance evaluation coefficient of variation



Conclusion

- Approximate available resources:
  - good prediction of available resources
  - holistic approach

- Queue Management and Custodian Election policies:
  - adaptability: any protocol, as long as we can combine functional and technical criteria
  - control: can choose the degree of replication
  - resource usage: low and well levelled
    - minimising # of exhausted nodes

THANK YOU !

Questions ?