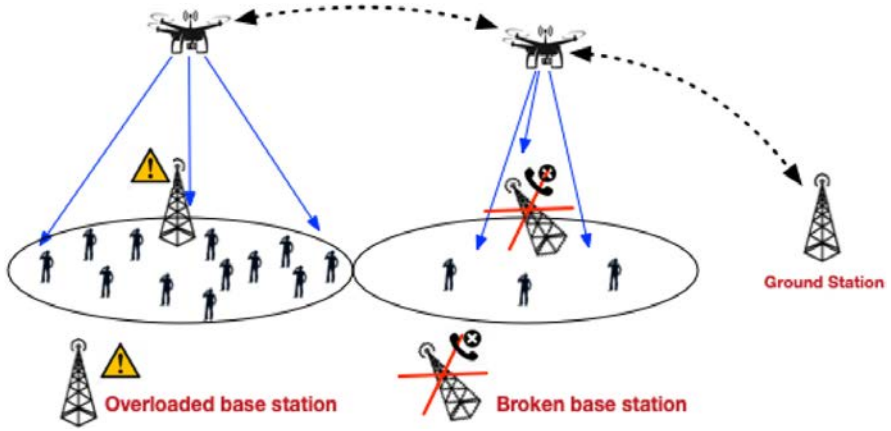
ON THE ASSISTANCE OF UNMANNED AERIAL VEHICLE TO WIRELESS CELLULAR SYSTEMS

Vicente Casares-Giner[1], *Xiaohu Ge*[2], *Yuxi Zhao*[2]
[1] *Universitat Politècnica de València (Spain)*
[2] *Huazhong University of Science and Technology (China)*
vcasares@upv.es, {xhge, zhao_yuxi}@hust.edu.cn

Outlines

- Introduction.
- System description
- The model
- The QBD process.
- Some results
  - The blocking probability.
  - The forced termination probability.
  - The handover probability.
  - The distribution of the number of calls forced to terminate.
  - The distribution of the number of handovers between UAVs.
- Conclusions.
- Further work.
- Basic references.

Introduction



UAV as BS deployed in flash crowd and emergency situations to provide temporary mobile network access

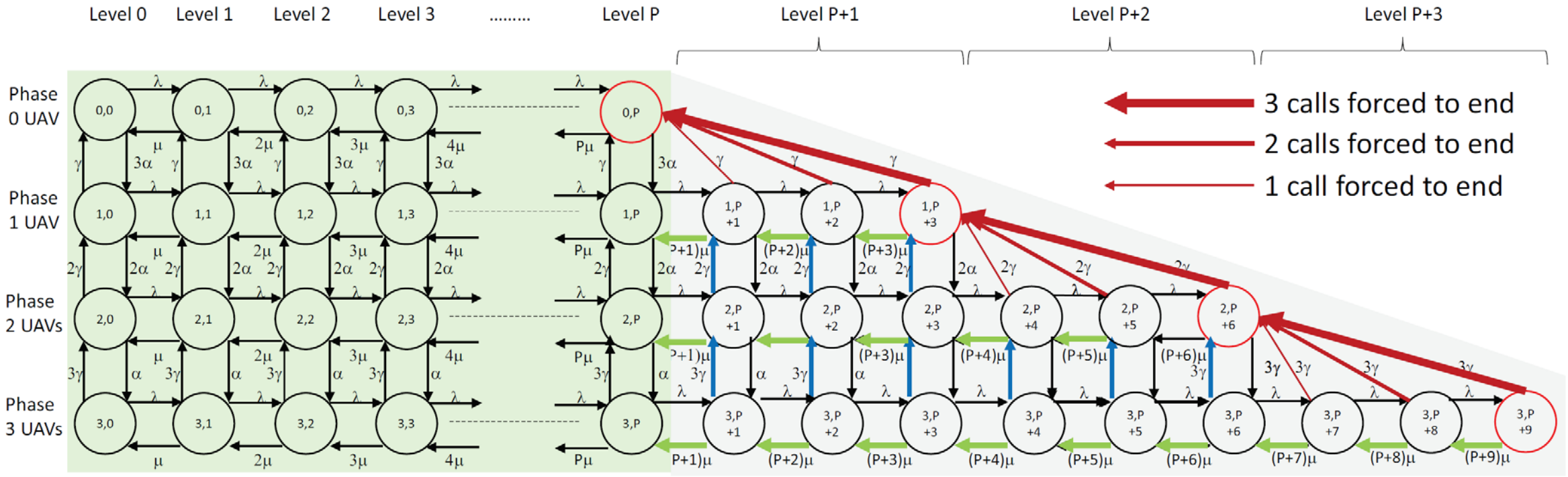
From : Z. Zhao, P. Cumino, C. Esposito, M. Xiao, D. Rosário, T. Braun, E. Cerqueira, and S. Sargento, “Smart Unmanned Aerial Vehicles as base stations placement to improve the mobile network operations” Computer Communications, vol. 181 (2022) pp. 45–57.

- We consider the cooperation of Unmanned Aerial Vehicles (UAV) with wireless cellular mobile systems.
- UAVs provide additional capacity to cellular Base Stations (BSs) when BSs are saturated or down.

The model

- There is one single BS with P primary channels.
- A finite number V of UAVs, are occasionally present in the coverage area of the BS.
- The presence -absence of one UAV follows an on-off process. Each UAV is equipped with S secondary channels.
- One incoming call is assigned to any free channel of the BS. If all channels of the BS are busy, the call is assigned to any free channel of any present UAV. If all channels of the present UAVs are busy, the call is lost.
- Arrival calls follow the Poisson process.
- Service calls are exponentially distributed.
- The presence/absence of one UAV follows the exponential/exponential distribution.

The QBD Process

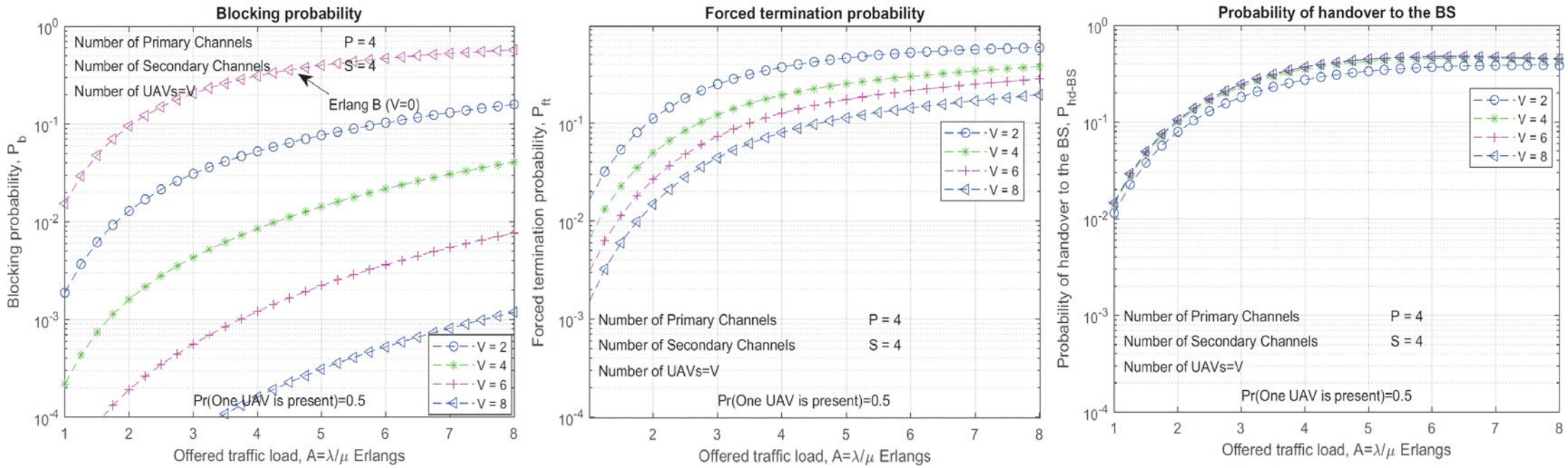


- Level: number of calls in progress.
- Phase: number of UAVs visible to the BS

Numerical Results

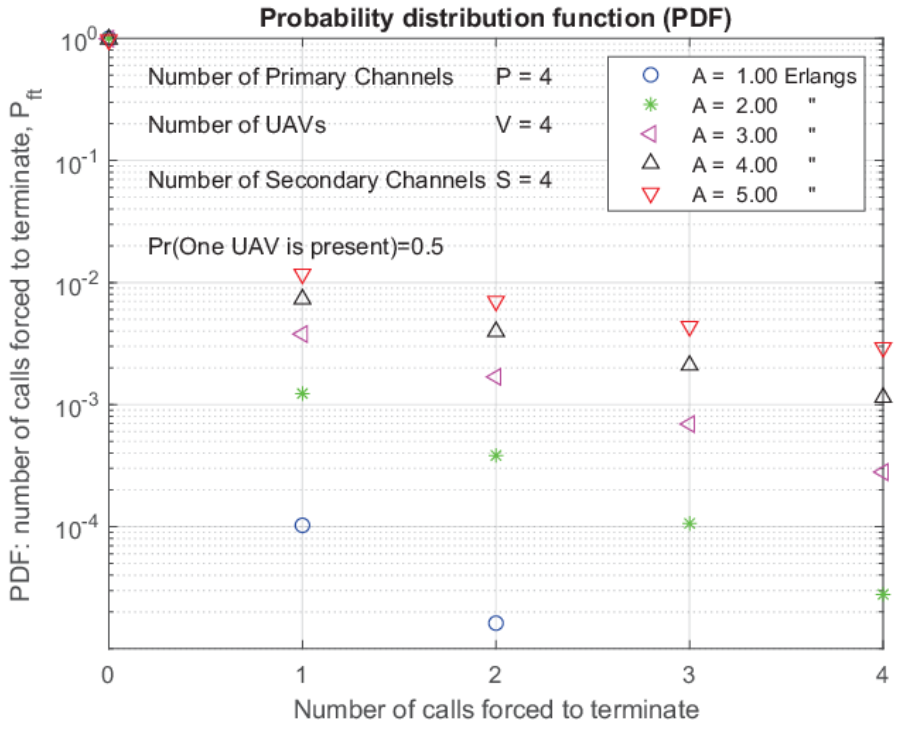
- We run the program to solve the QBD process in a standard way
- We set:
  - P=4 primary channels,
  - # of UAVs: V=2, 4, 6, 8,
  - S=4 secondary channels per each UAV
  - The fraction of time one UAV is in the system is equal to 0.5.
  - The offered traffic $A \in [1 : 0.25 : 8]$ Erlangs.

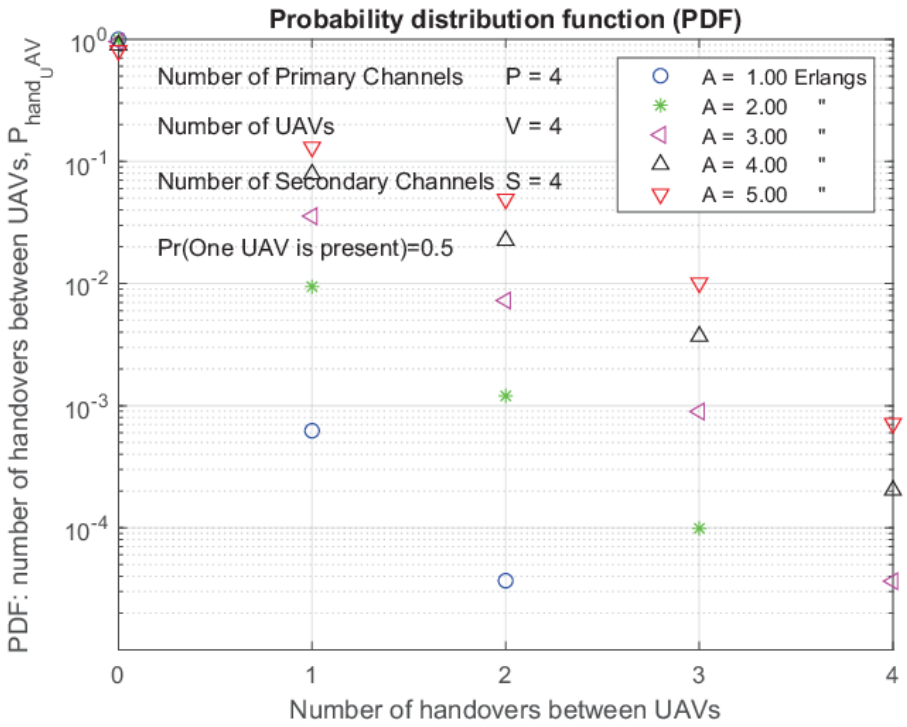
Blocking, forced termination and handover probabilities



- Figure on the left; the **blocking probability**. Obviously, the lost probability increases when the offered traffic A increases.
- Figure in the middle; the **forced termination**. This is the probability than one arbitrary admitted call be forced to terminate because one UAV leaves the BS coverage area. Obviously, this probability increases as the offered traffic increases, as expected.
- Figure on the right; the probability that **one admitted call be transferred** from a secondary channel of one UAV to a primary channel of the BS. For a given offered traffic, this handover probability increases when the number V of UAVs increases; but this increase is very small.

PDF: # of calls forced to terminate and # of handovers between UAVs





- Figure on the left; the PDF of the number of **calls forced to terminate**.
- Figure on the right; the PDF of the number of **handovers between UAVs**.

Conclusions

- We consider the tele-traffic behavior of **one single** wireless cellular BS assisted by a set of UAVs that are present in the coverage area of the BS.
- We evaluate:
  - The blocking probability of fresh calls,
  - The forced termination probability of calls in progress,
  - The probability of handover a call from one UAV to the BS.
  - The PDF about the # of calls forced to terminate.
  - The PDF about the # of handovers between UAVs.
- We show that UAVs can substantially help to the cellular operators under severe restrictions of traffic load.

Further work

- To consider the tele-traffic behavior of **several** wireless cellular BS assisted by a set of UAVs.
- Traffic and mobility are essential models that are necessary to consider in order to be close to the reality.

Some basic references

- M. E. Rivero-Angeles, I. Villordo-Jimenez, I. Y. Orea-Flores, N. Torres-Cruz, and A. Pretelín Ricárdez, “Erlang-U: Blocking Probability of UAV-Assisted Cellular Systems”, Information 2024, 15, 192. https://doi.org/10.3390/info15040192
- Z. Zhao, P. Cumino, C. Esposito, M. Xiao, D. Rosário, T. Braun, E. Cerqueira, and S. Sargento, “Smart Unmanned Aerial Vehicles as base stations placement to improve the mobile network operations” Computer Communications, vol. 181 (2022) pp. 45–57.
- J. Kim, S. Kim, C. Ju and H. I. Son, “Unmanned Aerial Vehicles in Agriculture: A Review of Perspective of Platform, Control, and Applications”, in IEEE Access, vol. 7, pp. 105100-105115, 2019, DOI:10.1109/ACCESS.2019.2932119.
- F. Ahmed, J. C. Mohanta, A. Keshari and P. S. Yadav, “Recent Advances in Unmanned Aerial Vehicles: A Review” Arabian Journal for Science and Engineering; vol. 47, 7963–7984, 2022. https://DOI.org/10.1007/s13369-022-06738-0.

Questions, comments, ...

- Thanks to all of you for your attention.
- Questions?
- Comments?