Performance Analysis of MAC for Power-Line Communications

Christina Vlachou[1], Albert Banchs[2], Julien Herzen[1], Patrick Thiran[1]

[1]EPFL, Switzerland — firstname.lastname@epfl.ch

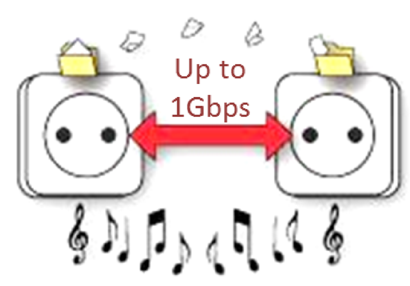
[2]IMDEA/Universidad Carlos III de Madrid, Spain — banchs@it.uc3m.es

Wireless Communications (WiFi) vs Power-Line Communications (PLC)

No additional wires to establish the physical network, employed for hybrid networks including multiple technologies

Very popular, fully explored

Simple CSMA/CA protocol



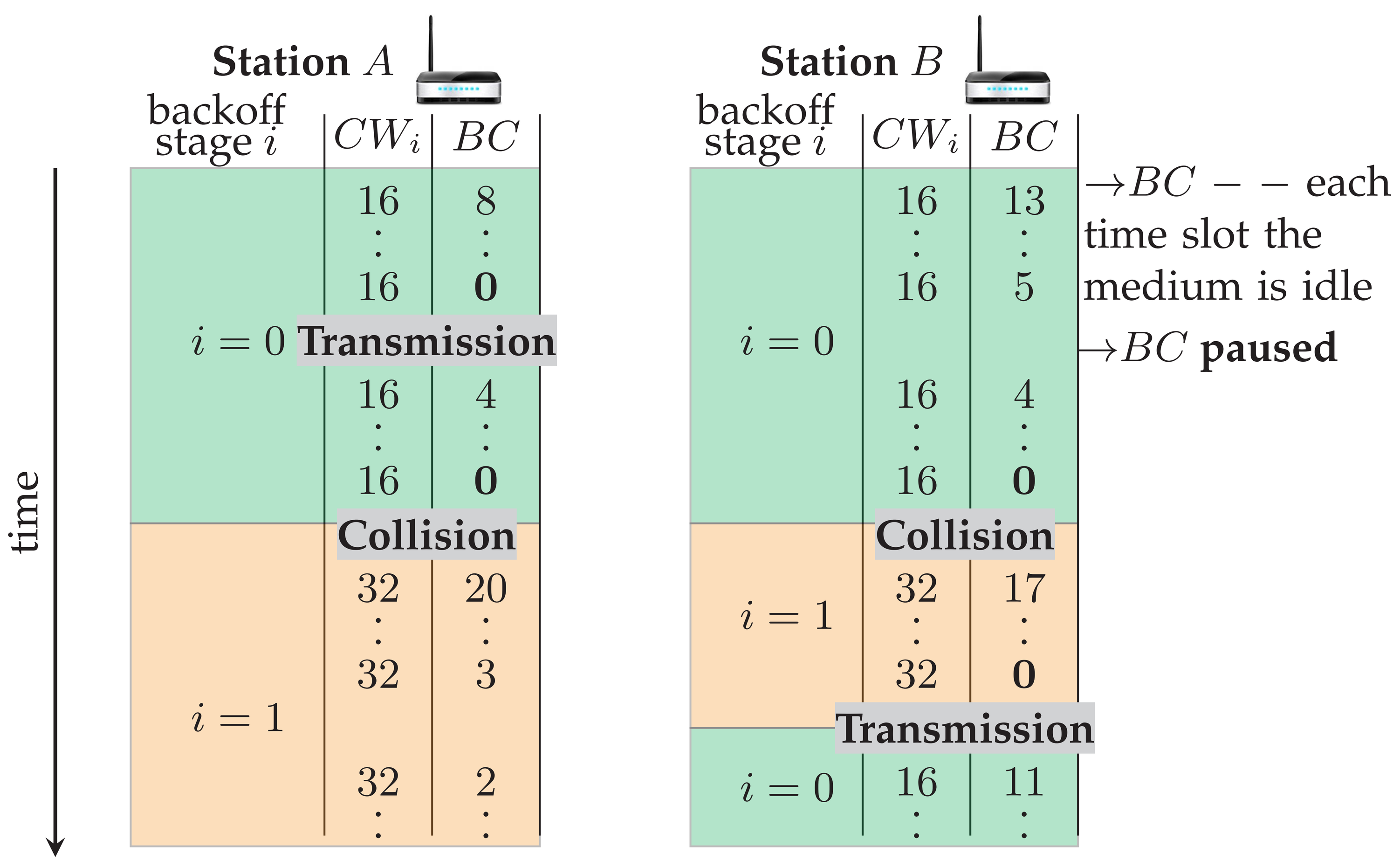
Becoming popular, MAC layer unexplored

Complex CSMA/CA protocol

MAC Layer of WiFi

Only one counter: backoff counter BC

At backoff stage i, BC chosen uniformly at random in $[0, CW_i - 1]$

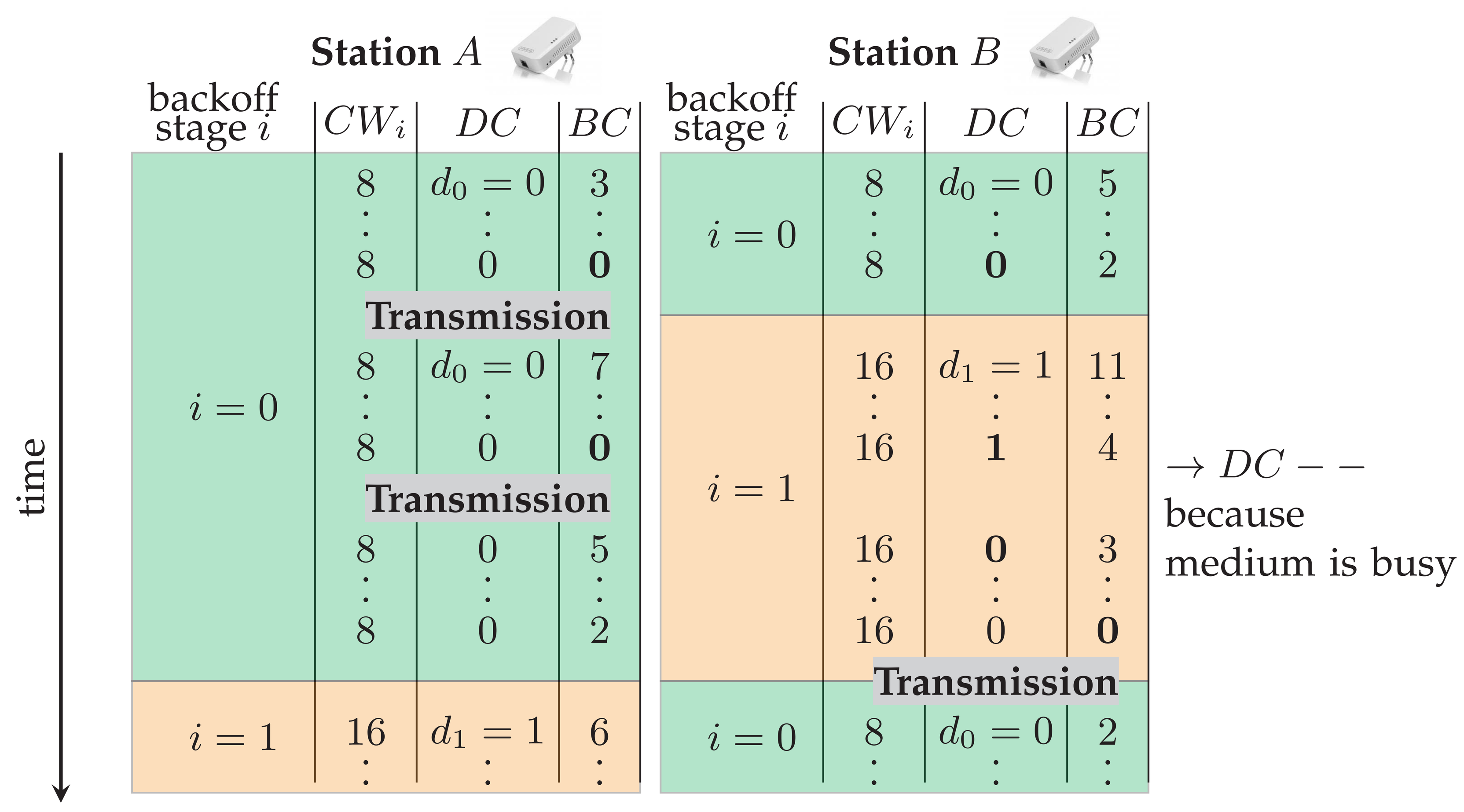


Backoff stage i changes **only** after a collision

MAC Layer of PLC

Two counters: backoff counter BC and **deferral counter** DC

At backoff stage i, BC chosen uniformly at random in $[0, CW_i - 1]$ and DC set at an initial value d_i



Backoff stage i changes **also** when the medium is sensed busy and $DC = 0$

Analysis of the Backoff Mechanisms

Scenario: N saturated stations in a single contention domain, infinite retry limit, m backoff stages

1) Decoupling Assumption:

Backoff processes of stations independent

Stations transmit with a time-invariant attempt probability τ

Stations collide with a time-invariant probability γ

Stations sense the medium busy with probability γ (PLC)

2) Theoretical Framework:

X: number of slots per successfully transmitted packet (renewal sequence)

R: number of attempts per successfully transmitted packet (reward)

By the renewal-reward theorem: $\tau = G(\gamma) = \mathbb{E}[R]/\mathbb{E}[X]$

Also, $\gamma = \Gamma(\tau) = 1 - (1-\tau)^{N-1}$, which yields the fixed-point equation $\gamma = \Gamma(G(\gamma))$

WiFi Backoff Analysis

Expected number of backoff slots at stage i:

$bc_i = (CW_i + 1)/2$, depends only on CW_i

At stage i, stations transmit with probability 1

Probability of successful transmission at stage i: $1 - \gamma$

$$\mathbb{E}[X] = \sum_{i=0}^{m-2} bc_i \gamma^i + \gamma^{m-1} \frac{bc_{m-1}}{1-\gamma}, \quad \mathbb{E}[R] = \frac{1}{1-\gamma}$$

Theorem. *[3] $\gamma = \Gamma(G(\gamma))$ has a unique solution if bc_i is non-decreasing with i.*

PLC Backoff Analysis

Expected number of backoff slots at stage i:

$bc_i(\gamma)$, a function of γ that depends on d_i, CW_i

At stage i, stations transmit with probability $t_i(\gamma)$ that depends on d_i, CW_i

Probability of successful transmission at stage i: $s_i = (1-\gamma) \cdot t_i(\gamma)$

$$\mathbb{E}[X] = \sum_{i=0}^{m-2} bc_i \prod_{j=0}^{i-1}(1-s_j) + \prod_{i=0}^{m-2}(1-s_i)\frac{bc_{m-1}}{s_{m-1}}, \quad \mathbb{E}[R] = \frac{1}{1-\gamma}$$

Theorem. *[4] $\gamma = \Gamma(G(\gamma))$ has a unique solution if bc_i/t_i is non-decreasing with i.*

Future Work

- Enhance PLC MAC layer using our model
- Investigate the accuracy of the decoupling assumption
- Investigate fairness aspects of the PLC CSMA/CA protocol

References

[1] Specifications: 1) IEEE Std 1901-2010, IEEE Standard for Broadband over Power Line Networks: MAC and Physical Layer Specifications. 2) HomePlug Alliance www.homeplug.org/

[2] Chung et al., Performance analysis of HomePlug 1.0 MAC with CSMA/CA in *JSAC July '06*

[3] A. Kumar, E. Altman, D. Miorandi, M. Goyal. New Insights From a Fixed-Point Analysis of Single Cell IEEE 802.11 WLANs. in IEEE/ACM Transactions on Networking, June '07

[4] C. Vlachou, A. Banchs J. Herzen, P. Thiran. Performance Analysis of MAC for Power-Line Communications in *ACM Sigmetrics '14*

Performance Evaluation of PLC MAC

Default PLC parameters:

$m = 4$, $CW_i \in \{8, 16, 32, 64\}$, and $d_i \in \{0, 1, 3, 15\}$