Pricing for Heterogeneous Services in OFDMA 802.16 Systems

Hakyung Jung, Seoul National University
Bruno Tuffin, INRIA Rennes – Bretagne Atlantique

Motivation

- IEEE 802.16 standard is expected to become a successful broadband wireless access solution, especially thanks to its ability to differentiate services with high data rates
- Pricing has indeed been seen as a way
  - to maximize provider’s revenue
  - to control demand and differentiate services for delivering a satisfactory quality of service (QoS)
- There is surprisingly no careful study about how pricing could be applied to control demand and efficiently differentiate services, although performance evaluation of WiMAX and its admission control have received a lot of attention in recent years
- Selected References

Performance model for OFDMA 802.16 [ICC06Elayoubi]

- Assumptions
  - We have $L$ classes of calls in an $n$-cell network
  - Class-$k$ calls arrive to a given cell $i$ with Poissonian rate $\lambda_{i,k}$, and require to be assigned $l_i$ sub-channels for an arbitrary distributed service time with mean $1/\mu_i$
- The proportion of symbols with degraded SNR for class-$k$ calls, $R(k)$:
  \[
  R(k) = \sum_{U_i} \frac{U_i}{K_0} \pi_{U_i}(U_i) \left[ \sum_{K_i} \left( \prod_{i=1}^{L} \Pi_i(K_i) \right) R(K) \right]
  \]
- $U_i$: the number of calls belonging to the $L$ classes in cell $i$
- $K$: the number of sub-channels in the $n$ cells
- $\pi_{U_i}(U_i)$: the probability of having $U_i$ class-$k$ calls in cell $i$
- $\Pi_i(K_i)$: the probability of having $K_i$ occupied sub-channels in cell $i$
- Blocking probability given class of service-$k$ in cell $i$, $B_{i,k}$:
  \[
  B_{i,k} = \sum_{U_i} \pi_{U_i}(U_i)
  \]

General utility model

- Valuation function $v_i(y)$ a class-$k$ customer gets for corresponding mean throughput $y_k$
  \[
  v_i(y) = y^{\alpha_i} \left( v_i(y) = y^{\alpha_i} \right)
  \]
  \[
  y_k = \delta_i \left( 1 - R(k) \right) \left( 1 - B_i \right)
  \]
- Implies that the high throughput is more valuable to higher class than the lower class

Utility function $u_i(\lambda_i)$ for any class-$k$ customer
- represents (financial) net benefit: valuation – access price $P_i$
  \[
  u_i(\lambda_i) = \lambda_i \left( 1 - R(k) \right) \left( 1 - B_i \right) - P_i
  \]
- This utility depends not only on the number of users in the given class-$k$, but also on the number in the other classes (due to collisions) $\rightarrow$ non-cooperative game theory

Equilibrium analysis of the game

- For a single class
  - Equilibrium value for arrival rate $\lambda_i$ for class-$k$ falls into two cases:
    1) $\lambda_i$ s.t. $v_i(\lambda_i) = 0$, meaning that the rate adapts itself up to saturation
    2) $\lambda_i = 0$ s.t. $v_i(\lambda_i) < 0$, meaning that access price is too expensive
- For two classes ($L=2$)
  - The equilibrium can be determined graphically. We have three possible situations.
    1) The curve $u_1(\lambda_1, \lambda_2) = 0$ is always above the curve $u_2(\lambda_1, \lambda_2) = 0$.
    2) The curve $u_1(\lambda_1, \lambda_2) = 0$ is always above the curve $u_2(\lambda_1, \lambda_2) = 0$.
    3) Two curves intersect

Price optimization

- From the network provider’s perspective, the main concern is to determine $P_1^*, P_2^*$ maximizing the network revenue
  \[
  R(P_1, P_2) = \lambda_1 P_1 + \lambda_2 P_2, \text{ with } P_1, P_2 \geq 0
  \]
  - We obtain the optimal prices numerically
    \[
    (P_1^*, P_2^*) = (0.65, 0.95), (0.75, 0.95), (0.85, 0.95)
    \]
    giving \[ R^* = R(P_1, P_2) = 7.24945 \]

Conclusion

- We have designed a pricing scheme for OFDMA 802.16 systems
- Future work could head into several directions:
  - The number of classes is more than two ($L > 2$)
  - Open classes where the users can choose the other classes