Bandwidth allocation in view of EMI on medical equipments in healthcare monitoring systems

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Introduction

Wireless networks, especially wireless LANs (WLANs) are widely studied in various e-health applications to help doctors gather and analyze the up-to-now information of patients. However, several challenges, including limited bandwidth, various quality of service (QoS) requirements for medical data transmission, and electromagnetic interference (EMI) on medical equipments, may reduce network capacity, namely the maximal potential number of patients supported by a wireless network. To enhance the capacity of this network, a novel bandwidth allocation scheme, subject to these challenges, is proposed. In addition, we propose a genetic theory based algorithm to maximize the capacity of patients. Finally, we analyze the capacity of patients supported by the WLAN in healthcare monitoring systems.

Optimal bandwidth allocation in view of EMI

WLAN is responsible for the transmission of traffic between patient devices and a monitoring center. The traffic in the WLAN mainly includes three categories: messages, video conferences and medical data with different QoS requirements. The problem of maximizing the capacity of patients can be described as equation (1)

$$\begin{aligned} &Max \quad N_u \\ &s.t. \quad M_i^{(k)} = Max\{(a_i^{(k)} - \eta_i^{(k)} B_i^{(k)})T_c + M_i^{(k-1)}, 0\} \le M_i^{\max} \\ &\qquad \sum_{i=1}^{N_u} B_i^{(k)} + B_a^{(k)} = S^{(k)}\Delta B + \sum_{i=1}^{N_u} B_i^{(k-1)} \le B_{total} \\ &\qquad a_i^{(k)} T_c \le \eta_i^{(k)} B_i^{(k)} \Delta T_1 \quad (i \in \mathbf{H}) \\ &\qquad a_i^{(k)} T_c \le \eta_i^{(k)} B_i^{(k)} \Delta T_2 \quad (i \in \mathbf{L}) \\ &\qquad P_i^{(k)} \le P_{\max}^{(k)}(i) \\ &\qquad r_i^{(k)} \le P_i^{(k)} \left|h_i^{(k)}\right|^2 \Big/ \left(B_i^{(k)} \sigma^2\right) \end{aligned} \tag{1}$$

where $\eta_i^{(k)}$ is the bandwidth efficiency for patient device i at time slot k; $P_i^{(k)}$ [W] is the transmit power of patient device i at time slot k; σ^2 [W/Hz] is the noise spectral density $r_i^{(k)}$ is the signal to noise ratio (SNR) for patient device i at time slot k; $h_i^{(k)}$ is the channel fading for patient device i at time slot k. To solve this optimization problem, we propose a genetic theory based algorithm, shown in Algorithm 1.

Input: The maximal potential amount of Bandwidth B_{total}, the bandwidth of one subcarrier ΔB, and the total number of time slots N_{T}
Output: The maximal number of patients supported by the WLAN
Step 1 Initialize N_{u}=0, S_{total}=0, S_{k}=0, given that S_{total} is the total number of subcarriers of N_{T} time slots
Step 2 Check whether $S_{\text{total}} \le B_{\text{total}}/\Delta B$. If so, $N_{\text{u}}=N_{\text{u}}+1$, go to step 3; Otherwise, go to step 4
Step 3 Given the N_{u}, allocate the bandwidth to attain the minimum of $\sum_{i=1}^{N_u} B_i^{(k)}$ at time slot k (k=1,2…N_{T})
Step 4 $S_i^{(k)} = max\left\{\left\lceil \left(\sum_{i=1}^{N_u} B_i^{(k)} + B_a^{(k)} - B^{(k-1)}\right) \Big/ \Delta B \right\rceil, 0\right\}$ and $S_{total} = S_{total} + \sum_{i=1}^{N_u} B_i^{(k)}$
Step 5 N_{u} is the maximal number of patients supported by this WLAN

Algorithm 1. Algorithm for the capacity of patients

Simulation and Discussion

The parameters in the simulation are as follows: N= 10000; ΔB=0.8Mbps; a_i=800kbps; T_c=0.1s; ΔT_1 = 0.5T_c; ΔT_2 = T_c. Based on Algorithm 1, we can obtain the capacity of patients in Fig.1. For a hospital, once the probability p is estimated by statistics, the capacity of patients supported by the WLAN could be estimated with our algorithm this information on capacity is necessary for the management of patients in wireless healthcare monitoring systems

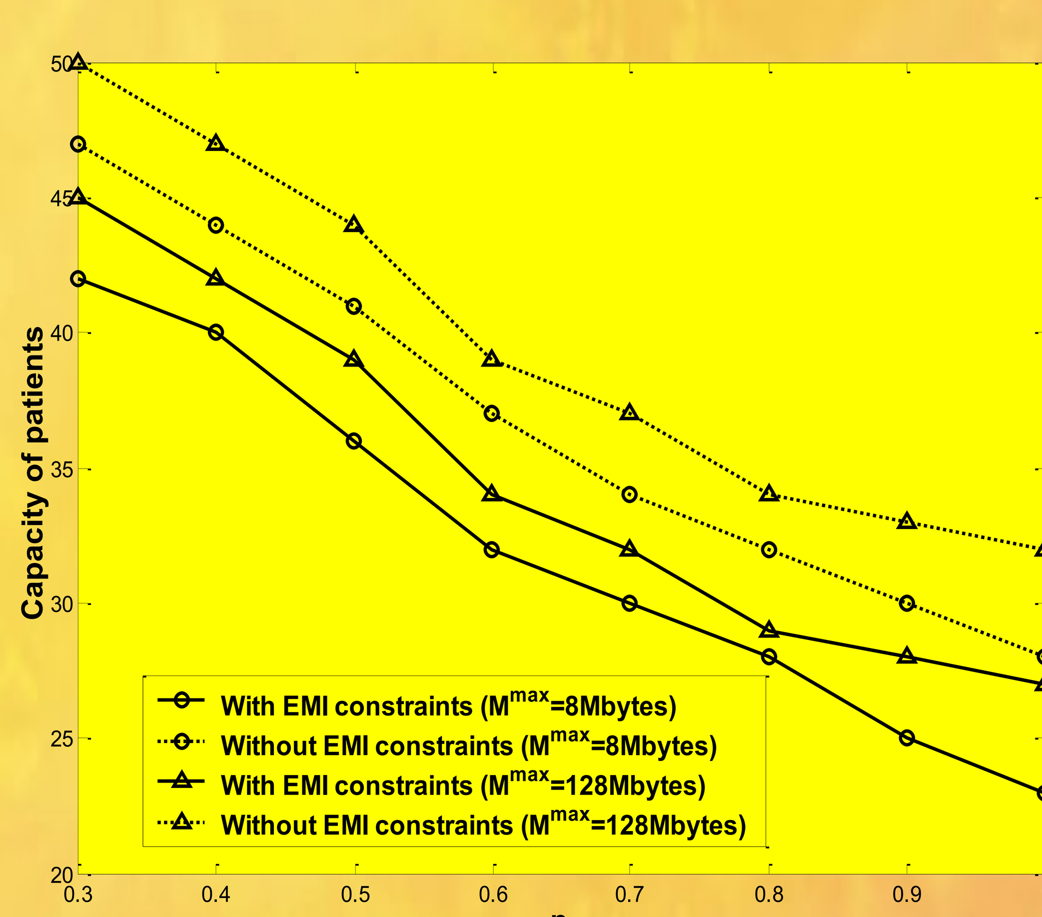

Fig.1. Capacity of patients supported in the WLAN

Conclusion

We propose a genetic theory based algorithm to enhance the capacity of patients in view of limited wireless bandwidth, QoS requirements, and EMI on medical equipments. Then, we analyze the capacity of patients supported by WLAN. Our work can offer some references for the management of patients in wireless healthcare monitoring.