Channel Capacity Comparison between Quorum Sensing and Electromagnetic-Based Communication within Bacterial Communities

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Our recent investigation into certain cellular structures indicates that bacterial cells within bacterial communities (biofilms) are capable of communicating using electromagnetic signals (N. Barani et al., IEEE APS/URSI, 2019). Within biofilms, there are elastic helical string called amyloid fibrils with permanent dipole charges on them. These strings have certain natural vibrational resonances at very high frequencies (due to their small size) that can be excited by the bacterial cells and thus radiate EM waves. Such structures can also go to vibration by an incident electromagnetic wave and their motion is sensed by the cell allowing reception/sensing of the field generated by other cells. Hence, cells communicate with each other and their surrounding environment by the means of amyloid fibrils playing the role of built-in antennas within biofilm. Another way of communication between the bacterial cells is quorum sensing (M. B. Miller et al., Annu. Rev. Microbiol, 2001). In quorum sensing, cells release chemical molecules that are diffused in the surrounding environment and are to be intercepted by the adjacent cells. Once captured, bacteria regulate their gene expression correspondingly.

In this work, in order to quantify the performance of these two communication approaches and find the corresponding pros and cons, two communication channel models are examined. The proposed channel models will allow for comparison of the corresponding channel capacities as well as bit error rate analysis associated with each communication tool within biofilms. For quorum sensing channel modeling, Fick's diffusion formula is combined with information theory equations (A. Einolghozati et al., IEEE Trans. on Communication, 2013). It is also assumed that the bacterial cells are all equipped with ligand receptors (A. Einolghozati et al., arxiv, 2012) and use OOK (On-Off Keying) modulation for message molecule transmission. For electromagnetic-based communication, a similar approach to what is applied in terahertz (THz) nano-communicatoin networks (J. M. Jornet et al., IEEE ICC, 2010) is followed to quantify the performance of such signaling.

In the presentation, we will detail the principles of operation of quorum sensing and electromagnetic-based communication and investigate the channel models developed for both of them. Finally, a comparison between the channel capacity, and bit error rate is performed to illustrate the advantages and disadvantages associated with each communication technique.