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جـــــامعــــة الملـــك فهـــد للبتـــرول والمعــــادن
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LP Formulation for Thermal Management of a Biosensor Network

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Objectives

To find an optimal policy that maximizes the life of a biosensor implanted in the human body and keeps the temperature of biosensor within the operable and safety zone.

Problem Statement

- A biosensor network consists of a set of surgically implanted sensors in human body to monitor its metabolism.
- In case of any abnormality these sensors transmit relevant data to medical personnel.
- A biosensor dissipates heat when transmitting data, which can damage the surrounding tissues.
- Due to acute nature, biosensor network must perform its functionality under safe-for human conditions.
- So, a certain policy has to be devised that will maximize lifetime of a biosensor under safety constraints.

Methodology

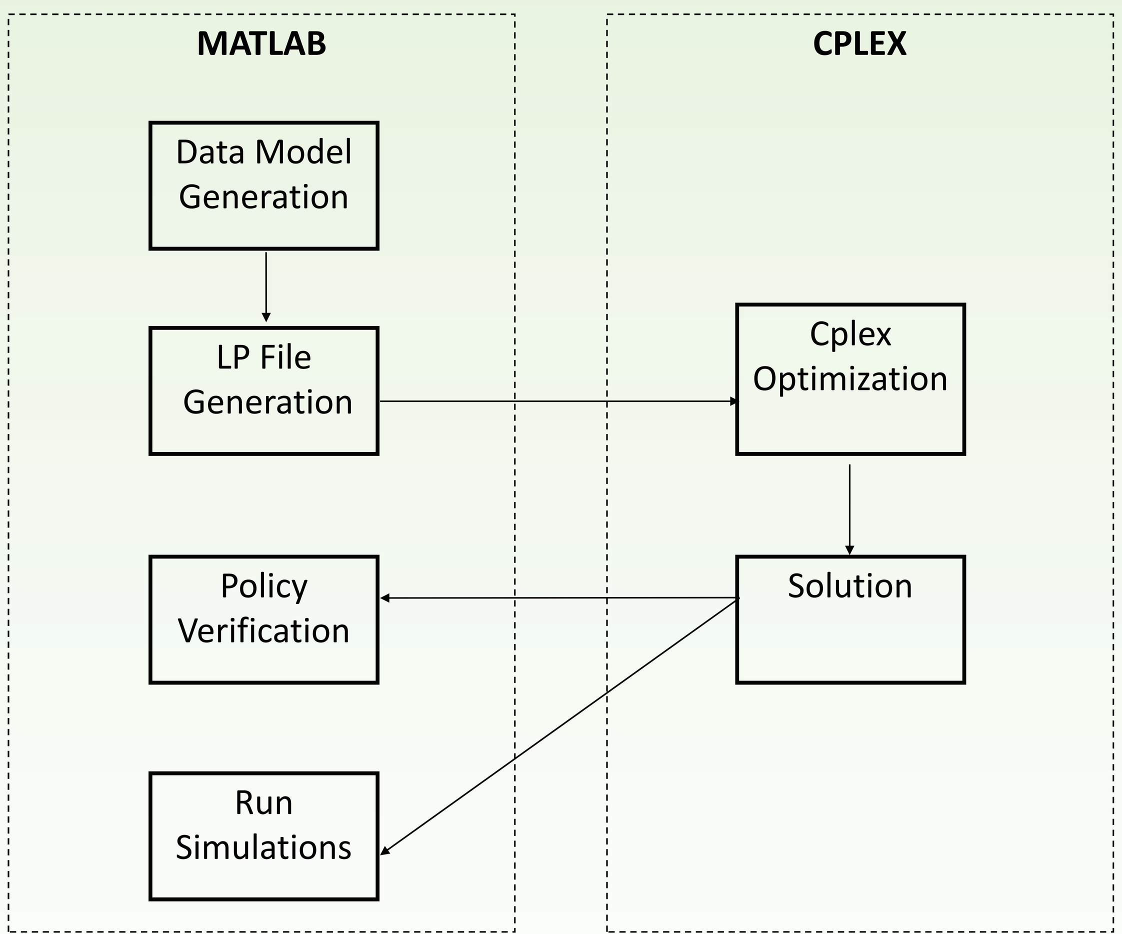
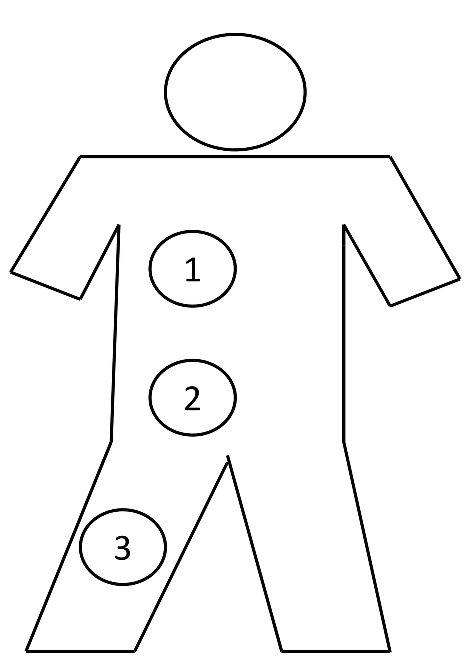


Figure 1: Steps to solve the model

Sensor	Energy	Temperature
Transmitting Sensor	Decrease by W(i)	F(T(i), W(i))
Neighbor Sensor	Remain Same	F(T(i), W(i))
Others	Remain Same	Decrease by τ

Table 1: Biosensor Dynamics

System Model



$$Neighbors = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Figure 2: A patient with 3 biosensors implanted in his body

LP Formulation

Our model consists of following main components.

State set

For Π set of biosensors at time *t*, $|S| = |T|^{|\Pi|} \times |E|^{|\Pi|} \times |W|^{|\Pi|}$

Where, T: Temperature, E: Energy and W: Transmission energy.

To make sure that safety requirements of a biosensor are met, the system will terminate if any of the following two constraints is true.

a) If temperature crosses a pre-defined threshold T_{max}

b) A biosensor cannot transmit its measurement due to lack of enough energy i.e. $E_t(i) < W_t(i)$

Action set

The action set defines a set of possible actions that can be taken by the biosensor network. In our case, it is the number of biosensors in the system.

Reward Function

Unit reward for successful transmission, $R(s,a) = 1,\ where\ s \in S, a \in A$

Transition probability function

$$P[s_{t+1} | s_t, a = k] = \prod_{i \in \Pi} \{P[T_{t+1}(i) | T_t(i), W_t(i), a = k] \times P[E_{t+1}(i) | E_t(i), W_t(i), a = k] \times P[W_{t+1}(i) | W_t(i)]\}$$

Where $P_{s_t, s_{t+1}}(a)$ is the probability that choosing an action *a* when in state s_t will lead to state s_{t+1}.

Objective function

Maximize $\sum_{s \in S} \sum_{a \in A} R(s,a) X(s,a)$

subject to Constraints

1. $\sum_{a \in A} X_{ja} - \beta \sum_{i \in S} \sum_{a \in A} P_{i,j}(a) X_{ia} = \alpha_j, \forall j \in S$

2. $X_{ia} \geq 0, \forall i \in S\ and\ a \in A$

Where, 0 < b < 1 is a discounting factor and a_j can be chosen arbitrarily, as long as they are positive. In our model, we choose b = 0.9 and a_j = {1/number of initial states ∀ j ∈ initial states, 0 otherwise}.

Results

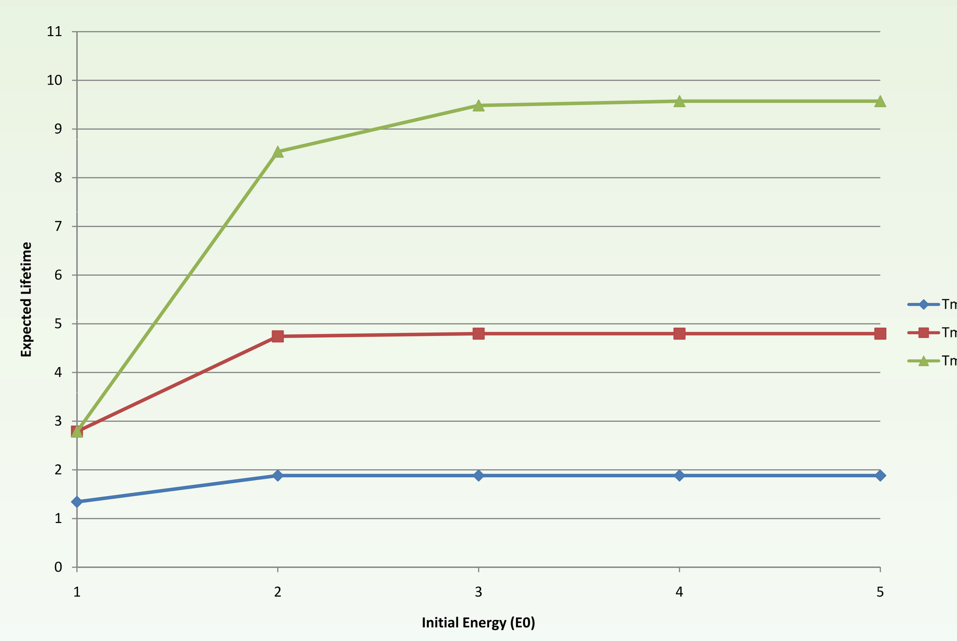


Figure 3: Expected network lifetime vs. initial energy for different values of T_{max}.

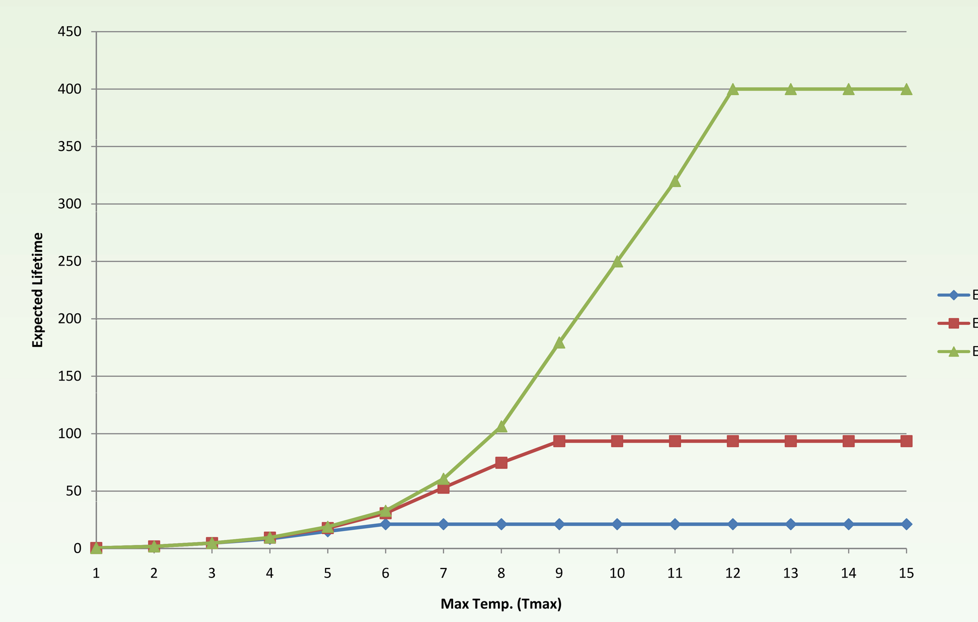


Figure 4: Expected network lifetime vs. maximum temperature for different values of E_0.

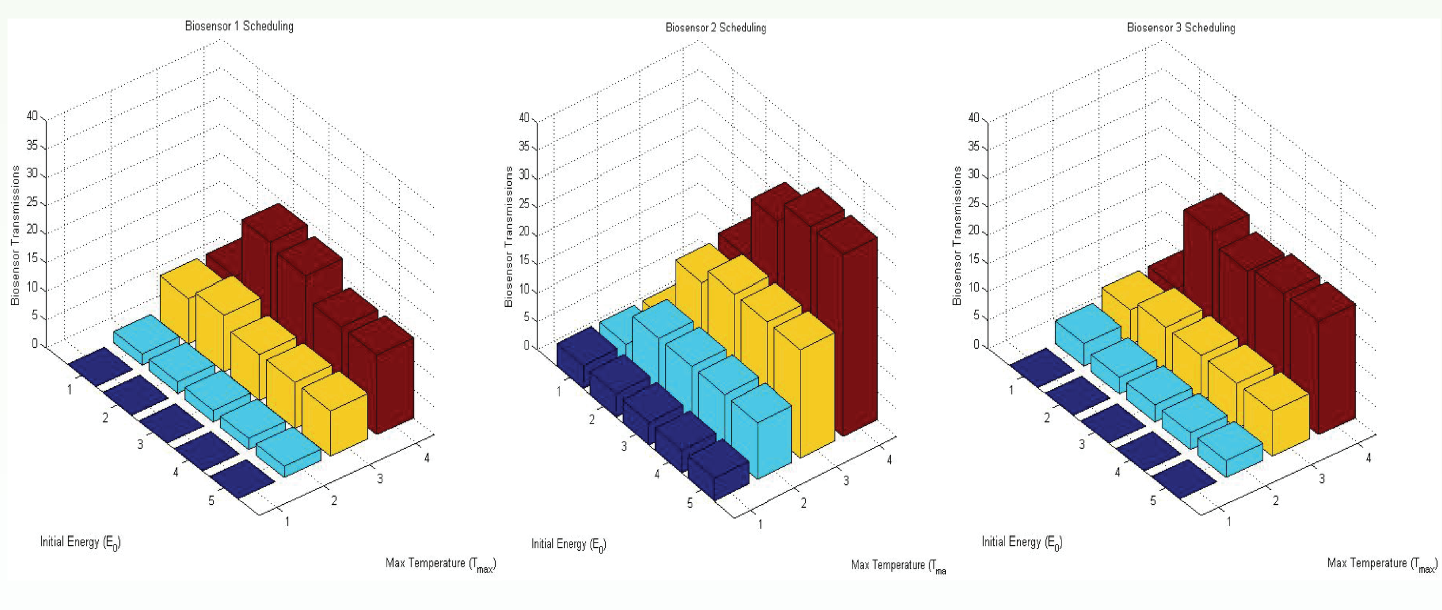


Figure 5: Biosensors scheduling for number of states within the policy for different levels of T_{max} and E_0.

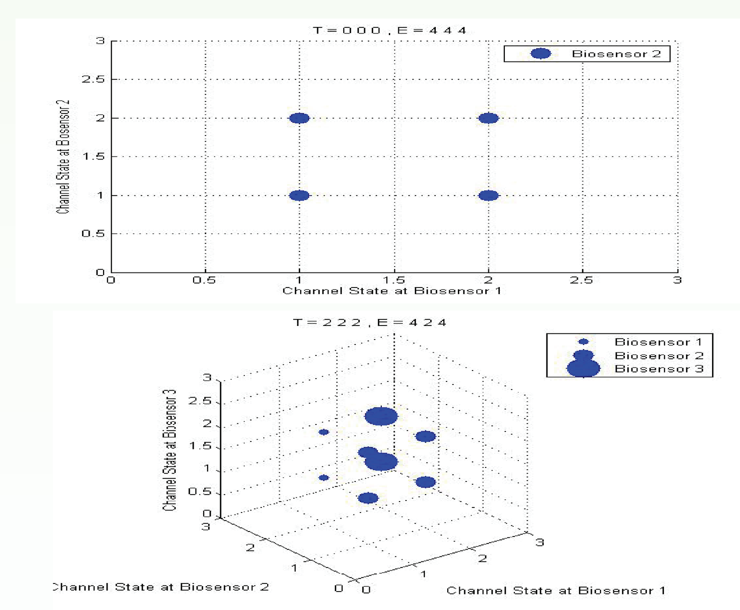


Figure 6: Policy Characterization

Conclusion

To select an optimal action (biosensor to transmit) within a biosensor network is not a trivial task. We have to consider plethora of constraints to make decision for a biosensor to transmit implanted in a human body to avoid harmful effects on surrounding tissues. We apply discounted cost linear programming model to get an optimal policy for biosensor scheduling but unable to found a general pattern in these selections. The overall trend of the network lifetime is found to be correct. The optimal policy gives the best balance between transmission energy consumption and the resulting temperature increase.

References

[1] Yahya Osais, F. Richard Yu and Marc St-Hilaire, "Thermal Management of Biosensor Networks", IEEE CCNC 2010 proceedings.

[2] Diego Bello and German Riano, "Linear Programming Solvers for Markov Decision Processes", IEEE Systems and Information Engineering Design Symposium, Charlottesville, VA , pp. 90–95, 2006.

[3] Y. Chen, Q. Zhao, V. Krishnamurthy, and D. Djonin, "Transmission scheduling for optimizing sensor network lifetime: A stochastic shortest path approach," IEEE Transactions on Signal Processing, vol. 55, no. 5, pp. 2294–2309, May 2007.

[4] Q. Tang, N. Tummala, S. Gupta, and L. Schwiebert, "Communication scheduling to minimize thermal effects of implanted biosensor networks in homogeneous tissue," IEEE Transactions on Biomedical Engineering, vol. 52, no. 7, pp. 1285–1294, July 2005.