Chapter 2

Preliminary concept

2.1 Introduction

This chapter describes short introduction of different methods applied in this thesis for congestion, admission and power control in communication networks. The chapter also contains a definition and explanation of the various parameters of communication networks. The main focus of this chapter is on discrete time sliding mode control scheme for “congestion control” and “admission control”, which is explained here with suitable mathematical background and simulations.

2.2 Introduction to Wireless Networks

The wireless network is a fast growing and exciting research area that has attracted considerable research attention in the recent past. All design issues addressed in the thesis is by considering wireless sensor network as a reference because congestion, admission and power control is not necessary for existing internet or TCP/IP networks. This has been fueled by the recent tremendous technological advances in the development of low-cost sensor devices equipped with wireless network interfaces. The creation of large-scale sensor networks
interconnecting several hundred to a few thousand-sensor nodes opens up several technical challenges and immense application possibilities. Sensor networks find applications spanning several domains including military, medical, industrial, and home networks. Wireless sensor networks have moved from the research domain into the real world with the commercial availability of sensors with networking capability. Any wireless sensor network consists of four basic components,

1) An assembly of distributed or localized sensors: These distributed or localized sensor nodes are used to measure physical quantity and send that information to sink node and other sensor nodes.

2) An interconnecting network: All sensor nodes in WSN are interconnected through mostly wireless link hence referred as wireless sensor network (WSN). This wireless communication is achieved using various technologies like Zigbee™ or MiWi™.

3) A central point of information clustering: The information acquiresd by sensor nodes are gathered and monitored at this central point of information clustering.

4) A set of computing resources at the central point: These resources are used to handle data correlation, event trending, status querying, and data mining [73]. The general WSN architecture is shown in Fig. 2.1.

As shown in Fig. 2.1, all remote sensor nodes and clustering nodes (intermediate processing node) form “sensor field.” These all remote sensors (or sensor nodes) are communicating wirelessly to its pre-allocated clustering node (intermediate processing node). This wireless communication is achieved by single- or multi-hops based on the type of WSN whether it is of a mesh or star based. These clustering nodes gather information and pass it to final processing node, which has set of computational resources, storage and databases required to monitor the desired physical quantity in WSN [73].
2.3 Introduction to Various Control Parameters of Wireless Communication Systems

Wireless communication systems are highly nonlinear system, which requires having control of each and every stage without compromising delay in the network. Classically in any communication network, a master can apply bandwidth utilization control, power utilization control, admission control, traffic control, flow and congestion control, collision control, error control, QoS control, routing control etc. Some of the important control parameters of communication network are explained below.
QoS Control:
Consider the data communication between two nodes, where a node is well equipped with a processor, which can transmit / receive and process the signal. Circuit switching and packet switching are the technique, which can be used for data communication between two nodes. If the source has a message longer than the capacity, it divides the message in number of packets and transmits. Each packet contains portions of a massage and some control security information according to protocols. The goal of each protocol is to maximize the network resources utilization while satisfying the individual users QoS requirements. To increase the quality of services (QoS) in any network, system required coordinated use of admission control, congestion control, traffic access control, packet scheduling, and buffer management [10].

Admission Control:
Admission control limits the number of users supported by the system according to the available resources. The admission control mechanism has to decide acceptance and rejection of new request according to the various algorithms used to implement the process. [10]

Traffic Access Control:
Traffic access control algorithm controls the number of users in a system. Once the user request is accepted by an admission control mechanism and the available resources are not enough, the user request can be blocked or can be delayed [10].

Flow and Congestion Control
In all types of communication network, the size of data required to be transmitted is always higher than the capacity of the link. Thus, when multiple users want to share the same channel due to this congestion occurs. Eventually the buffer space may be exhausted and some packets might get lost [10].
2.4 Sliding Mode Control

Variable structure control systems, as the name suggests, are class of systems whereby the “control law” has deliberately changed during the control process according to some define the rules of the state of the system [13]. For example, consider the double Integrator system given by

\[ \dot{y}(t) = u(t) \]  

(2.1)

Consider the feedback control law for the system is,

\[ u(t) = -ky(t) \]  

(2.2)

Where \( k \) is strictly positive scalar.

one way of analyzing is a phase portrait may be analyzed to understand the close loop action, which is a plot of velocity against the position. Now put the value of Eqn. 2.2 into Eqn. 2.1 and multiply both sides with \( y \),

\[ \dot{y}y = -kyy \]  

(2.3)

Integrating Eqn. 2.3 gives the relationship between velocity and position like this

\[ \dot{y}^2 + ky^2 = c \]  

(2.4)

Where \( c \) is a constant of integration and it is strictly positive.

Eqn. 2.4 shows the equation of a circle with center at the origin and radius \( \sqrt{c} \) as shown into the Fig. 2.2. In general, a plot of \( \dot{y} \) vs. \( y \) is an ellipse. As shown into the Fig. 2.3, which is actually inappropriate since the \( y \) and \( \dot{y} \) variable do not move towards origin. Now consider the control law from Eqn. 2.5 in place of control law given in Eqn. 2.2

\[ u(t) = \begin{cases} -k_1y(t) \text{ if } \dot{y}y > 0 \\ -k_2y(t) \text{ Otherwise} \end{cases} \]  

(2.5)
Figure 2.2: Phase portrait of simple sliding motion when $k = 1$ in Eqn. 2.4

Figure 2.3: Phase portrait of simple sliding motion when $k \neq 1$ in Eqn. 2.4
Figure 2.4(a): Phase portrait of simple sliding motion when $u(t) = -k_1y(t)$

Figure 2.4(b): Phase portrait of simple sliding motion when $u(t) = -k_2y(t)$
Where $0 < k_1 < l < k_2$ and the phase plane $(y, \dot{y})$ is partitioned by the switching surface into four quadrants separated by the axes.

![Diagram of phase portrait](image)

**Figure 2.5:** Phase portrait of the system under variable structure control

The control law $u = -k_2 y$ is effective in the quadrants of the phase plane labeled (i). In this quadrant distance of the phase portrait from the origin decreases along the phase trajectory. Same way in quadrant (ii) the control law $u = -k_1 y$ is effective where the distance between the phase portrait and origin decreases along the phase trajectory as shown in Fig. 2.6. In this way, the phase portrait must be in the shape of spiral towards the origin as shown into the Fig. 2.5.

This concept can be proven by considering this function,

$$V(y, \dot{y}) = y^2 + \dot{y}^2$$

(2.6)

Eqn. 2.6 shows the Pythagoras' theorem and represents the square of the distance from the point $(y, \dot{y})$ to the origin. The time derivative of the $V(y, \dot{y})$ is given by Eqn. 2.7.
\[ \dot{V} = 2yy + 2yy = 2\dot{y}(y + u) \] (2.7)

\[ u(t) = \begin{cases} -1 & \text{if } s(y, \dot{y}) > 0 \\ 1 & \text{if } s(y, \dot{y}) < 0 \end{cases} \] (2.8)

Where the switching function is defined by

\[ s(y, \dot{y}) = my + \dot{y} \] (2.9)

Where \( m \) is a positive scalar, the switching function is used to decide which control law is in use from the Eqn. 2.8. The Eqn. 2.8 may be represented as

\[ u(t) = -\text{sgn}(s(t)) \] (2.10)

Where \( \text{sgn}(\cdot) \) is the signum function.
2.5 State -Space Approach

For higher order control systems, state-space models are more suitable choice for the analysis. To test and validate various control strategies on wireless communication systems, state-space models have been used. To represent sliding mode based control scheme shown in Section 2.2 in state space form consider once again the double integrator given in Eqn. 2.1 as

$$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$  \hspace{1cm} (2.11)

Where

$$x = \begin{bmatrix} y \\ \dot{y} \end{bmatrix}$$

The switching function presented in Eqn. 2.9 can be expressed as

$$s(y, \dot{y}) = s.x(t)$$ \hspace{1cm} (2.12)

Where

$$s = [m \hspace{0.5cm} 1]$$

2.6 Chattering Effect in Sliding Mode Control

A proper sliding motion occurs when the state trajectory $y(t)$ and $\dot{y}(t)$ of the controlled system follow the desire trajectory at every time samples. This requires switching between numbers of control laws at a very fast rate. Because of this high speed, switching between numbers of control laws occurs and system states oscillates within finite levels, these oscillations; called as chattering, which is shown in Fig. 2.7. Chapter 4 contain in detail analysis of the chattering effect in sliding mode control
2.7 Conclusions

Sliding mode control based controllers are robust, as the external disturbances may not affect the performance of the control system. Sliding mode based controllers are working on two step process; design of sliding surface and design of control law, so implementation is easier on low profile hardware. The only problem with sliding mode control is chattering effect because it is an on/off controller. For high-speed communication systems, implementation of sliding mode controller is challenging.