# 15-712: Reading Assignment

Jonathan Moody

October 31, 2001

## 1 Time, Clocks, and the Ordering of Events in a Distributed System

1. The authors start with a partial ordering of events, and extend this to a total ordering. Different logical clock implementations (different ways of numbering events within a process) lead to different total orderings. To deal with this and the problem of "anomalies", the notion of a synchronized system of physical clocks is introduced.

2. Simply ordering events by when they are received at a centralized server can lead to some strange situations. Client sends message A to server then message B to another client. In response the client also sends a message C to the server. It is possible that C would arrive before A!

3. The algorithm for resource allocation presented in the paper requires a process to broadcast its intentions and wait for acknowledgement from all other processes with a timestamp $\geq$ to that of the original request message.

4. Anomalous behavior is avoided by reducing the error in the local physical clock to a number smaller than the time $\mu$ required to transmit messages between processes of the system. For example, $\mu$ could be chosen based on the speed of light and the minimum distance between any two processes. This makes it impossible to observe an anomaly by transmitting messages outside of the system.

## 2 The Byzantine Generals Problem

1. I admire the way the authors reduced/simplified a complex problem stated in natural language to the problem of one general sending values $v_i$ to his and his $i$ lieutenants.

2. It is only possible to achieve consensus among the loyal generals using "oral" messages if fewer than $\frac{1}{3}$ of the generals are traitorous.

3. Cryptographic signing makes the problem easier because lieutenants can compare the messages they receive and determine who is sending different messages to different people. The only way a traitor can escape detection is to play along, sending consistent messages to everyone, which enables the loyal generals to make the right decision.

4. I initially thought this was connected to error correcting codes, but no, error correcting codes are simpler because one receiver can look at all the message bits at once. With the Byzantine Generals problem, each lieutenant receives only part of the message, thus it must broadcast what it received to the remaining lieutenants so that the whole message can be reconstructed.

5. In the case where communication pathways are limited, each General must be connected to 3 times the number of traitors present.