

#### SSC07-X-10

# A Simple Time Synchronization Scheme for Satellite Clusters in Formation Flying

Dao Thi Hong Diep

N. Nagarajan

Nanyang Technological University, Singapore

# Objective

- To formulate a time synchronization strategy for satellites in formation.
- Analyze and establish the feasibility by simulation.

# Need

- For navigation among satellites in formation.
- For precise electronic steering of the beams of the satellites to synthesize very large antenna structures.



# Contents

- Synchronization in Fireflies
- Proposed 'Transmit & Listen' method
- Calculation and correction of the clock offsets
- Simulation results by Matlab
- Conclusion



Synchronization in Fireflies

- Synchronization in Fireflies is a selforganized process.
- Fireflies influence each other.
- Emit flashes periodically and receptive to flashes from others



 Synchronization accuracy is governed by the propagation delay in the line-of-sight





- Whenever A wants to synchronize with respect to B, it transmits a pulse which is reflected back by B.
- B also periodically transmits pulses





Aug-07

SSC07-X-10

7



### Next transmission of A is delayed (or advanced) by $\tau$ or a fraction of it ( $k\tau$ )



### Single step and progressive correction offsets

$$t_{A,2} = t_A + NT + \tau$$
  
=  $t_A + NT + \left(n_{BA} - \frac{n_{AA}}{2}\right)T$   
$$t_{B,2} = t_B + NT$$
  
=  $t_A + NT + \tau$   
=  $t_A + NT + \left(n_{BA} - \frac{n_{AA}}{2}\right)T$ 

$$t_{A,2} = t_A + NT + k\tau$$
$$t_{B,2} = t_B + NT$$
$$= t_A + NT + \tau$$

Offset in  $2^{nd}$  cycle is,  $(1-k)\tau$ 

Offset in  $p^{th}$  cycle is,  $(1-k)^{p-1}\tau$ 

Assumption: Clock Frequencies of A and B are same



### Synchronization with Unequal Clock Frequencies

$$Clock Periods: T for B and T+\delta for A$$

$$t_{A,2} = t_A + N(T+\delta) + k\tau \qquad t_{B,2} = t_B + NT$$

$$= t_A + NT + k\tau + N\delta \qquad = t_A + NT + \tau$$

$$Offset in the nth cycle,$$

$$\tau_n = (1-k)^{n-1}\tau_1 - \{ (1-k)^{n-2} + (1-k)^{n-3} + \dots + (1-k) + 1 \} N\delta$$

$$This leads to, \quad \tau_n = (1-k)^{n-1}\tau_1 - \frac{1}{k}N\delta$$

Result: Unequal frequencies lead to a fixed offset at the start of each cycle

10

### Synchronization with Unequal Clock Frequencies

- 1. Initiate synchronization.
- Calculate the offset (τ) and apply progressive correction by factor k
- 3. Repeat step 2 in each cycle and monitor  $\tau$
- 4. If  $\tau$  is constant after say 50 cycles, add an **additional correction (i.e. Look-ahead correction)** of  $k\tau_n$  (which is equal to N\delta) in timing the subsequent pulses of A.
- 5. This brings the offset to  $\tau_n = (1-k)^{n-1} \tau$ , for n > 50.



# Simulation results by Matlab

Typical Formation of 4 nano-satellites around a mother satellite (B)

		Parameter	Nodes					
	A2		1	2	3	4	5	
B 0m	<b>_</b> A4	Clock Period (nSec)	0.1	0.1 0.75e-4	0.1+ 1.1e-4	0.1 0.85e-4	0.1 0.65e-4	
		Clock freq (GHz)	10	10.0075	9.989	10.0085	10.0065	
		Initial Offset (Counts)	0	5504	3496	5504	7004	
		Node Status	М	С	С	С	С	
		Legend: M–Mother, C-Child						



d = 30

A3

## Simulation results

#### Identical Clocks, with only an initial offset



#### Progressive Correction

k	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Offset	0	1	1	1	1	1	2	3	4	9



### Simulation results

#### Unequal Clock Frequencies, AND with an initial offset



# Conclusion and future work

- 'transmit and listen' method formulation is effective to time-synchronize in a formation.
- Feasible to remove the offsets due to initial mismatch and also the clock frequency differences.
- To set up an indoor UWB network with a distance of 10-20 m and conduct the experiments with 10GHz clock.





# Thank You





