# B6:The Ragtag Tag Team

Udit Ranasaria, Shiva Nathan, Rhea Kudtarkar

Problem Area & Use Case

- Real-Time Location System
- Records locations of each player on the court into a database
  - Software stacks are built to provide insights into coaching and player ability
- Ex: NFL "Next Gen Stats" and NBA "Advanced Stats"
- Extremely complex and expensive E2E systems
- Goal: Build an affordable sports RTLS
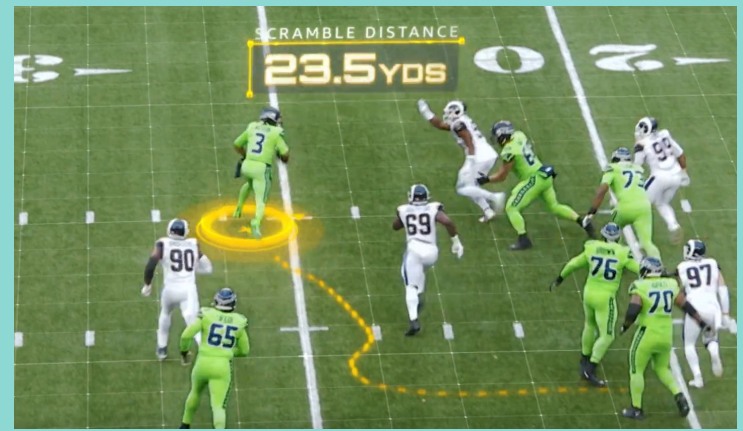
Scope for Capstone

- Indoor RTLS system
- Designed for basketball
- Focus on building the E2E system to get accurate tracking data
  - NOT focus on analytics software stack after getting data

Requirements

- Accuracy: Within 0.33 meters
- Frequency: Poll at 7 Hz
- Scale: 4 anchors and 10 tags
- Range: minimum 35 meters/anchor
- Battery Life: >=1 year per tag; 3hrs for Anchors
- Physical: Tags should not affect player, Anchors should blend
- Cost: Tags should be replaceable/cheap in bulk

Solution Approach: TWR vs TDoA

Two Way Ranging	Time Difference of Arrival
Easy anchor deployment	Complex anchor deployment
No anchor sync required	Requires precise anchor time sync
Computation done on tag/anchor	Computation pushed downstream to server
High message volume limits poll frequency	1-way messages enable fast polling freq
High power usage for Tags	Low power, cost, and size for tags
Light backhaul needed to server	Heavy backhaul needed to server
Simple location computation	Complex location computation

Solution Approach: Key Technical Challenges

- Heavy backhaul volume (1 Mbps)
  - Use RaspPi at anchors to stream data through Wifi/BLE5
- Precise Time Sync at anchors (<10ns diff between anchors)
  - Use RTC/TCXO chip to keep local drift low (2ppm)
  - Implement time sync algo over UWB between anchors
- Complex Location Computation/Algorithms (multilateration)
  - Read papers and debug hard
- Designing low-interference communication chips
  - UWB was designed for low-interference in short term LoS blocks
  - Decawave has off-the-shelf UWB chips that we will repurpose with custom firm/software

Solution Approach: Design

- **Tags:** Decawave DWM1004C
- **Anchors:** DWM1001 + RaspPi + DS3231 TCXO
- **Server:** Laptop + Algorithm
- **Connectivity:**
  - UWB from tags to anchors
  - Wi-Fi/BLE5 from anchors to server
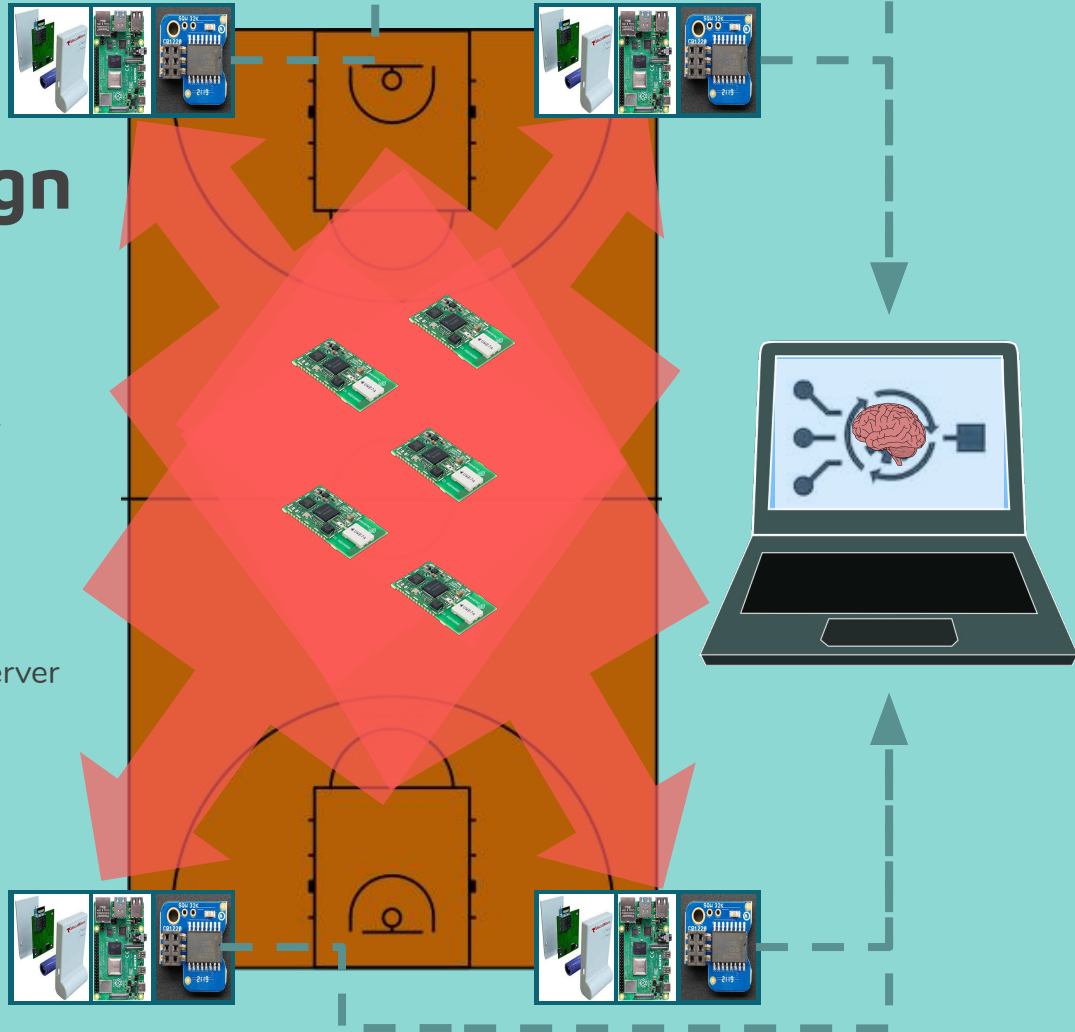
Testing, Verification, Metrics

Requirement	Metric Goal	Test Method
Accuracy	0.33 meters	Field Test: Measure fixed locations and verify calculated location is within desired goal
Tag-anchor poll freq and range	7Hz @ 35 meters	Field Test: Anchors can receive tag pulses within target range at target frequency rate without loss
Anchor Life	3 hours	Lab Test: Run dummy system and measure time
Anchor Time Sync	<10ns	Unit Lab Test: Currently researching test methods Integrated Field Test: Measure drift in timestamp difference for fixed tag location
Server receives time-stamped messages	1Mbps throughput w/o loss	Unit Lab Test: Send noise messages at required throughput and have no loss
End to end integration	Works for basketball game!	Field Test: Have players wear tags for a game and measure above requirements

Area Breakdown

Signals and Systems

- Processing UWB signal from tag on anchor
- Processing Time Sync UWB signal
- Designing full backhaul network

Software Systems

- Pulse software on tags
- Timestamp software on anchors
- Time sync software between anchors
- Localization computation algorithms on server

Task and Expertise Division

Shiva

Focus on anchor-server communication design

Backhaul throughput calculations

Choosing protocol for anchor backhaul

Rhea

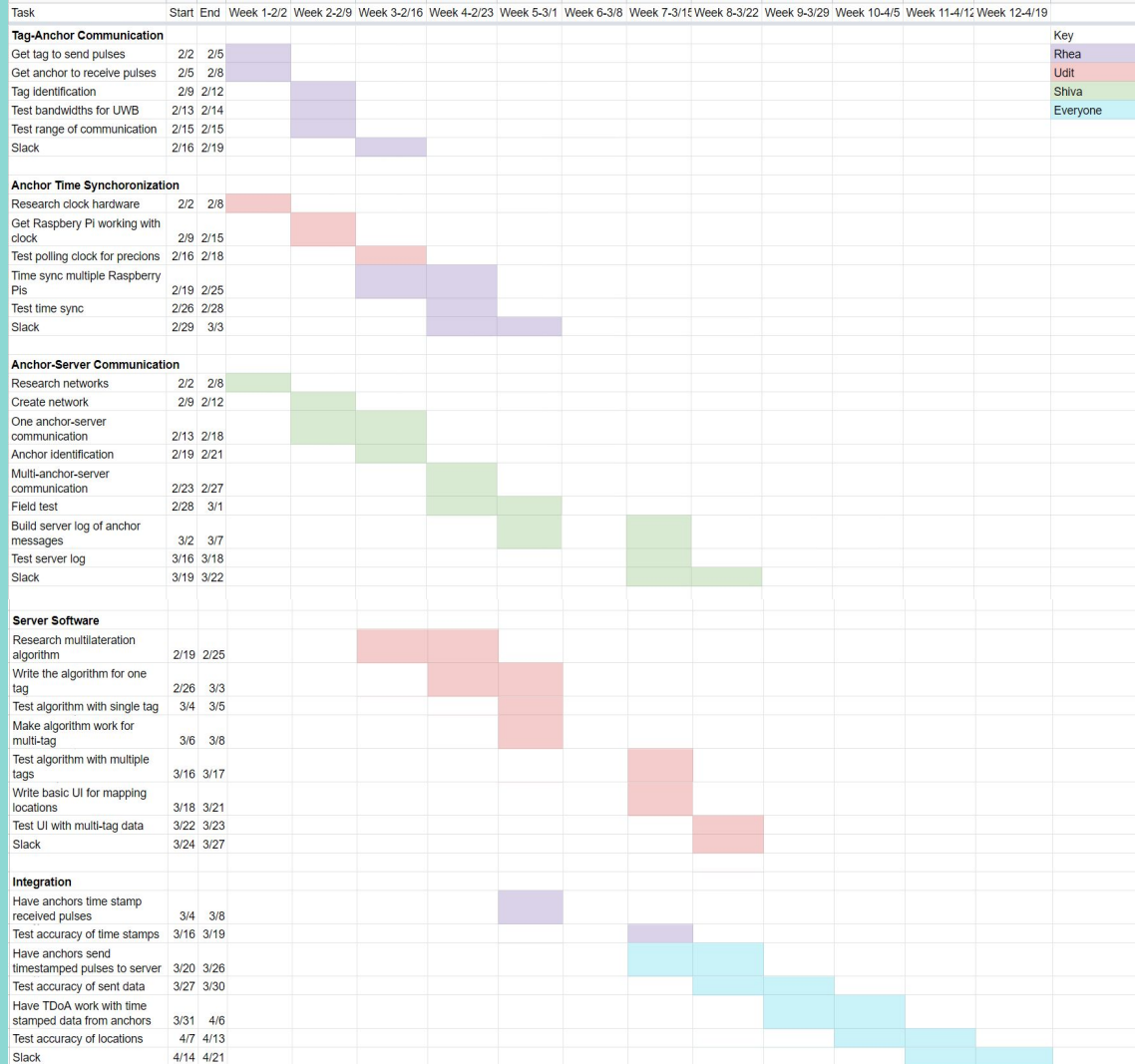UWB Signal Processing

Time Sync Software

Udit

Time Sync Hardware

Mapping algorithm software

Gantt Chart

Task	Start	End
Tag-Anchor Communication		
Get tag to send pulses	2/2	2/5
Get anchor to receive pulses	2/5	2/8
Tag identification	2/9	2/12
Test bandwidths for UWB	2/13	2/14
Test range of communication	2/15	2/15
Slack	2/16	2/19
Anchor Time Synchoronization		
Research clock hardware	2/2	2/8
Get Raspbery Pi working with clock	2/9	2/15
Test polling clock for precions	2/16	2/18
Time sync multiple Raspberry Pis	2/19	2/25
Test time sync	2/26	2/28
Slack	2/29	3/3
Anchor-Server Communication		
Research networks	2/2	2/8
Create network	2/9	2/12
One anchor-server communication	2/13	2/18
Anchor identification	2/19	2/21
Multi-anchor-server communication	2/23	2/27
Field test	2/28	3/1
Build server log of anchor messages	3/2	3/7
Test server log	3/16	3/18
Slack	3/19	3/22
Server Software		
Research multilateration algorithm	2/19	2/25
Write the algorithm for one tag	2/26	3/3
Test algorithm with single tag	3/4	3/5
Make algorithm work for multi-tag	3/6	3/8
Test algorithm with multiple tags	3/16	3/17
Write basic UI for mapping locations	3/18	3/21
Test UI with multi-tag data	3/22	3/23
Slack	3/24	3/27
Integration		
Have anchors time stamp received pulses	3/4	3/8
Test accuracy of time stamps	3/16	3/19
Have anchors send timestamped pulses to server	3/20	3/26
Test accuracy of sent data	3/27	3/30
Have TDoA work with time stamped data from anchors	3/31	4/6
Test accuracy of locations	4/7	4/13
Slack	4/14	4/21

Week columns: Week 1-2/2, Week 2-2/9, Week 3-2/16, Week 4-2/23, Week 5-3/1, Week 6-3/8, Week 7-3/15, Week 8-3/22, Week 9-3/29, Week 10-4/5, Week 11-4/12, Week 12-4/19

Key:
- Rhea
- Udit
- Shiva
- Everyone

Conclusion

- Well scoped project
  - Risk-management: wired backhaul; switch to TWR
  - Stretch Goals: Outdoor football field, ML-based sport-specific stack, auto-location of anchors
- Tentative cost is low
  - ~130$ per anchor, 20$ per tag
- Major impact for high schools and colleges!