Quantum Key Distribution GUI

A Real-Time Data Visualization Tool

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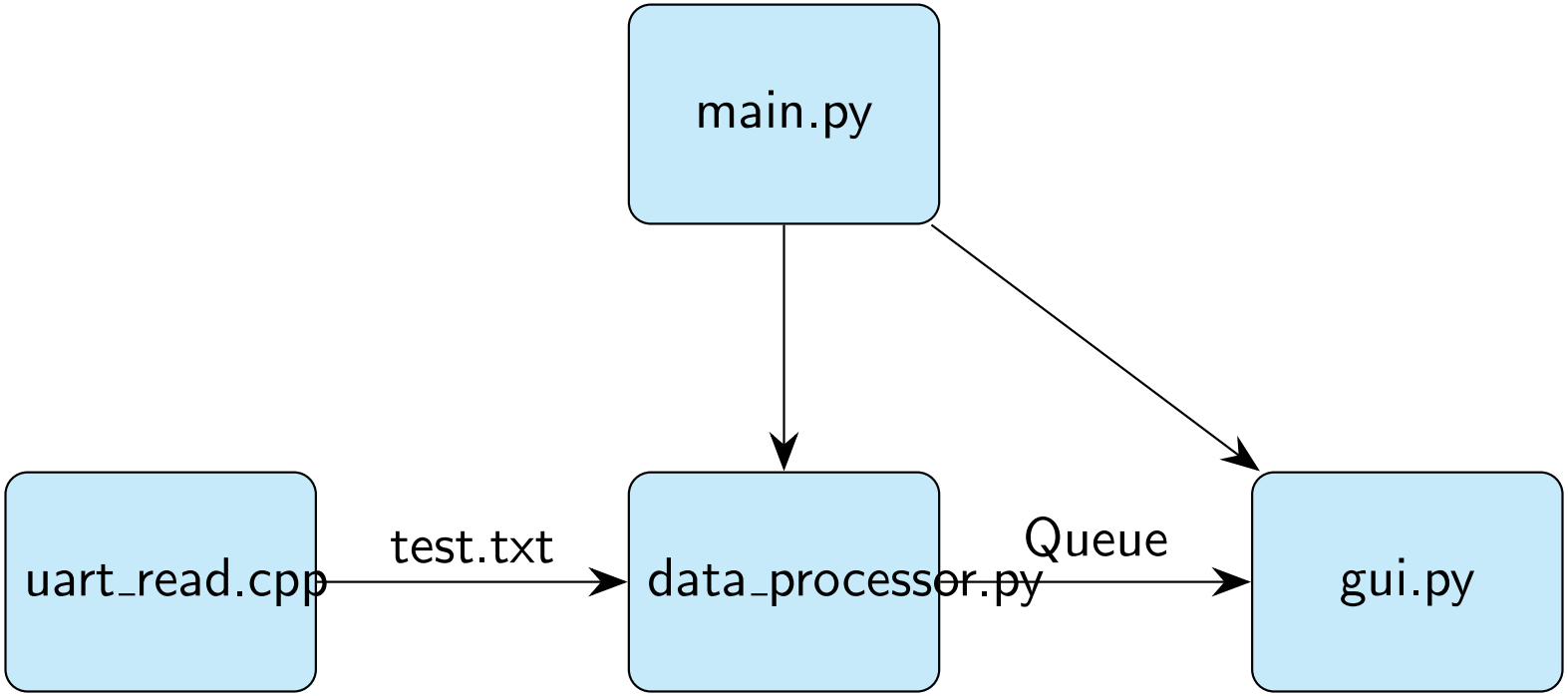
July 28, 2025

Project Overview

- **Purpose**: Visualize Quantum Key Distribution (QKD) metrics in real-time.
- **Features**:
  - Tabbed GUI with histograms and line plots
  - Supports file and console (UART) data input
  - Real-time visualization of QBER, throughput, visibility, keys
  - Session management and mode switching
- **Technologies**:
  - Python: PyQt6, pyqtgraph, pyserial, NumPy
  - C++: Windows API, C standard library

System Architecture



- `main.py` initializes application
- `uart_read.cpp` reads serial data to `test.txt`
- `data_processor.py` parses data and queues it
- `gui.py` visualizes data in real-time

File Analysis: main.py

- **Purpose**: Application entry point
- **Key Functions**:
  - Initializes mode, `DataProcessor`, and `MainWindow`
  - Sets up PyQt6 application loop
- **Code Snippet**:

```
1  def main():
2      mode = "file"
3      if len(sys.argv) > 1 and sys.argv[1] in ["console", "file"]:
4          mode = sys.argv[1]
5      data_queue = Queue()
6      processor = DataProcessor(data_queue, mode=mode, input_string="default_input")
7      app = QApplication(sys.argv)
8      window = MainWindow(data_queue, processor)
9      window.show()
10     sys.exit(app.exec())
```

File Analysis: gui.py

- **Purpose**: GUI for real-time QKD data visualization
- **Key Features**:
  - Tabbed interface: Overview, SPD1, SPD2, QBER, Throughput, Visibility, SPD1 Decoy
  - Plots: Histograms (40 bins, 0–4000 ps), line graphs (60s window)
  - Interactive: Tooltips, marquee, mode switching
- **Code Snippet** (Plot Update):

```
1  def update_plots(self):
2      try:
3          for _ in range(50):
4              data = self.data_queue.get_nowait()
5              current_time = time.time() - self.start_time
6              if data['type'] == 'qber':
7                  qber_val = float(data['value'])
8                  self.qber_x_all.append(current_time)
9                  self.qber_y_all.append(qber_val)
10                 self.qber_line_all.setData(self.qber_x_all, self.qber_y_all)
```

File Analysis: data_processor.py

- **Purpose**: Acquires and parses QKD data
- **Key Features**:
  - Modes: File (`output.txt`) or console (UART)
  - Parses session number, timestamps, QBER, keys, etc.
  - Threaded, queue-based data transfer
- **Code Snippet** (Parsing):

```
1  def parse_and_queue(self, line: str):
2      if line.startswith("QBER_VALUE_IS:"):
3          value = float(line.split(':')[1])
4          self.data_queue.put({"type": "qber", "value": value})
5          self.last_session_data["qber"] = value
6          self.session_data_types.add("qber")
```

File Analysis: uart_read.cpp

- **Purpose**: Reads UART data and writes to `test.txt`
- **Key Features**:
  - Configures serial port (115200 baud, 8-N-1)
  - Reads data into 256-byte buffer
  - Outputs to `test.txt` and `stdout`
- **Code Snippet** (Serial Read):

```
1  void readData(HANDLE hport, FILE *fp2) {
2      char buffer[256];
3      DWORD bytesRead;
4      while (1) {
5          if (ReadFile(hport, buffer, sizeof(buffer), &bytesRead, NULL)) {
6              if (bytesRead > 0) {
7                  for (DWORD i = 0; i < bytesRead; i++) {
8                      printf("%c", buffer[i]);
9                      fprintf(fp2, "%c", buffer[i]);
10                     fflush(fp2);
11                 }
12             }
13         }
14     }
15 }
```

Data Flow and Interaction

1. `uart_read.cpp` reads serial data, writes to `test.txt and also to console` simultaneously.
2. `data_processor.py` reads `test.txt` (file mode) or UART (console mode)
3. Parsed data queued to `gui.py` via `Queue`
4. `gui.py` updates plots every 20 ms
5. `main.py` coordinates initialization and mode selection

- **Session Management**: Synchronizes on `SESSION_NUMBER`, handles missing data
- Plots **previous session** data for missing data in **current session**
- **previous session** data is maintained using list

Visualization Features

- **Tabs**: Overview, SPD1/SPD2 Histograms, QBER, Throughput, Visibility, SPD1 Decoy
- **Plots**:
  - Histograms: 40 bins (0–4000 ps,each bin of size 100)
  - Line Plots: 30s window, dynamic y-axis(based on current window min and max value)
- **Interactivity**: Tooltips, marquee, mode toggle

Screenshots (Overview)

Figure: Overview of entire GUI

Screenshots (Plot_Overview)

Figure: plottting Overview of entire GUI

Screenshots (Individual_Plot_View)

Figure: Individual Plot View

Screenshots (File_Mode_View)

Figure: File Mode View

Screenshots (Console_Mode_View)

Figure: Console Mode view

Screenshots (Full_Key_On_Hover)

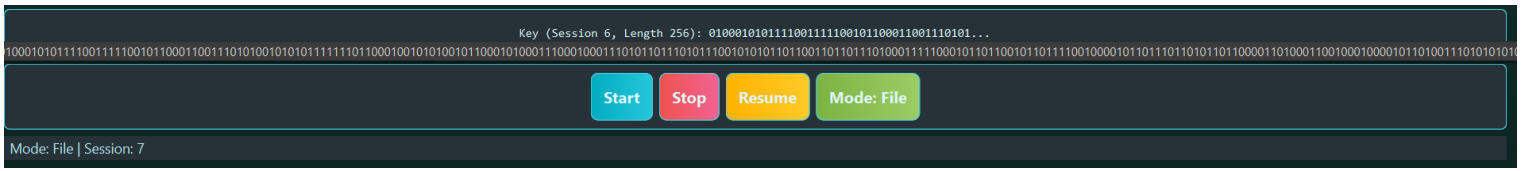


Figure: Display of entire key on hover

Challenges and Solutions

- **Challenge**: Real-time data processing
  - **Solution**: Threaded `DataProcessor`, queue-based transfer
- **Challenge**: Session data consistency
  - **Solution**: Default values for missing data, session tracking
- **Challenge**: GUI responsiveness
  - **Solution**: PyQt6 with 20 ms update interval

Conclusion

- **Summary**: A robust tool for real-time QKD data visualization.
- **Importance**: Enables efficient monitoring and analysis of quantum key distrubution data.
- **Next Steps**: Testing with real hardware, deployment, feature expansion

Questions?

Thank you!

Any questions?