Develop an Infinite Scrolling Newsfeed (like Facebook or Twitter)

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Problem Understanding

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Design an infinite scrolling newsfeed system that delivers personalized content to millions of users in real-time, similar to Facebook, Twitter, or Instagram. The system must handle content ranking, real-time updates, and seamless infinite scroll performance while maintaining user engagement.

Functional Requirements

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- **Infinite Scrolling**: Seamless content loading as user scrolls
- **Personalized Feed**: ML-driven content ranking and recommendation
- **Real-time Updates**: New posts appear without page refresh
- **Content Types**: Text, images, videos, links, polls, stories
- **Interactions**: Like, comment, share, bookmark, follow/unfollow
- **Feed Customization**: Sort by recency, relevance, trending
- **Content Discovery**: Hashtags, mentions, search, trending topics
- **Cross-platform**: Web, mobile apps with synchronized experience

Non-Functional Requirements

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- **Performance**: <200ms initial feed load, <100ms scroll response
- **Scalability**: 1B+ users, 100M+ posts/day, 10M+ concurrent users
- **Availability**: 99.9% uptime with graceful degradation
- **Consistency**: Eventually consistent feed across devices
- **Engagement**: High content relevance, minimal scroll latency
- **Responsiveness**: Smooth 60fps scrolling on all devices

Key Assumptions

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- Average user: 100 posts/day in feed, 20 interactions
- Peak load: 50M concurrent users, 100K posts/second
- Content variety: 60% text, 25% images, 10% videos, 5% links
- User engagement: Average 30min session, 200 posts viewed
- Feed refresh: Every 5-15 minutes depending on activity
- Content lifespan: 80% of engagement in first 24 hours

High-Level Architecture

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Global System Architecture

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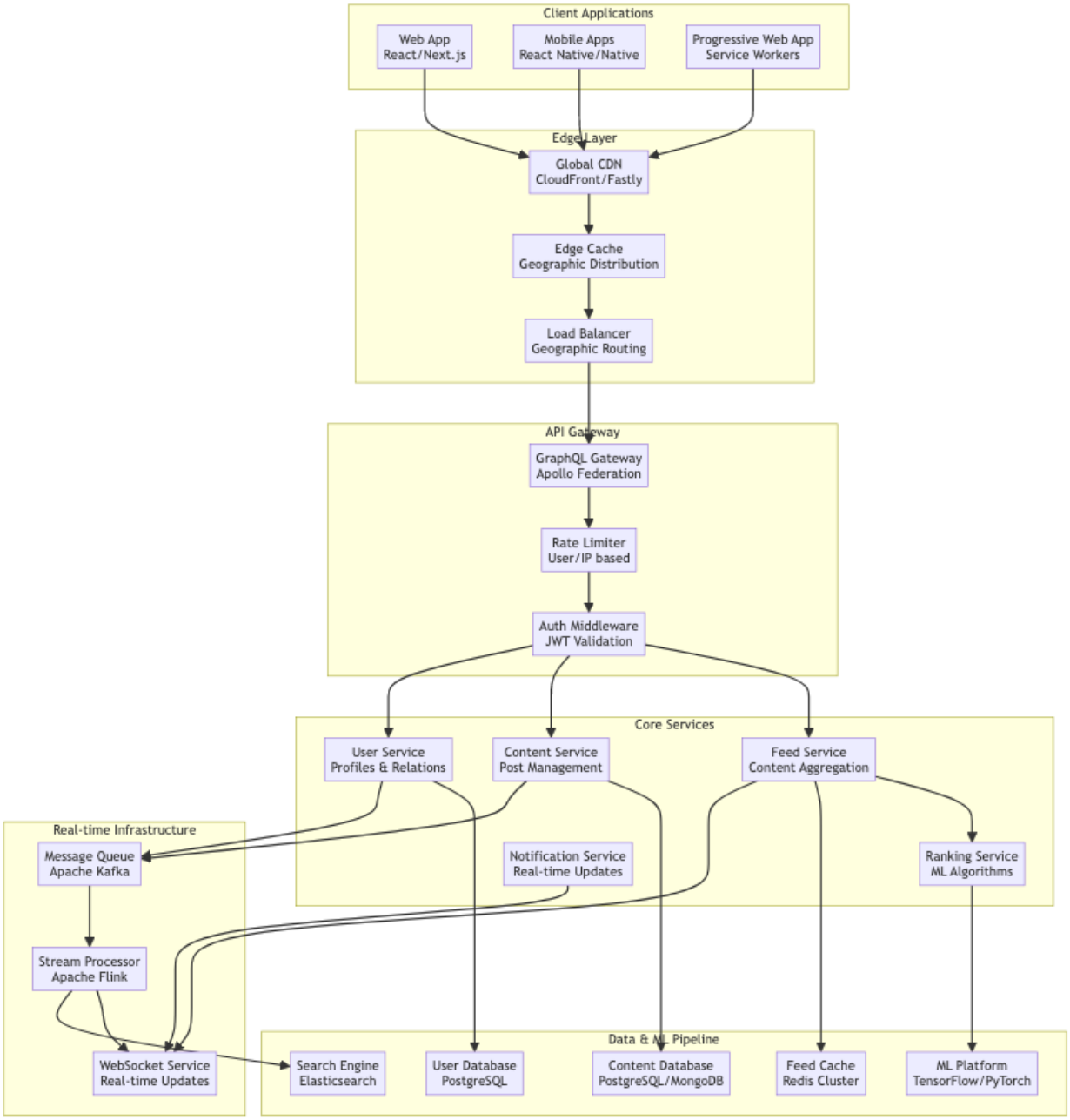

Feed Generation Architecture

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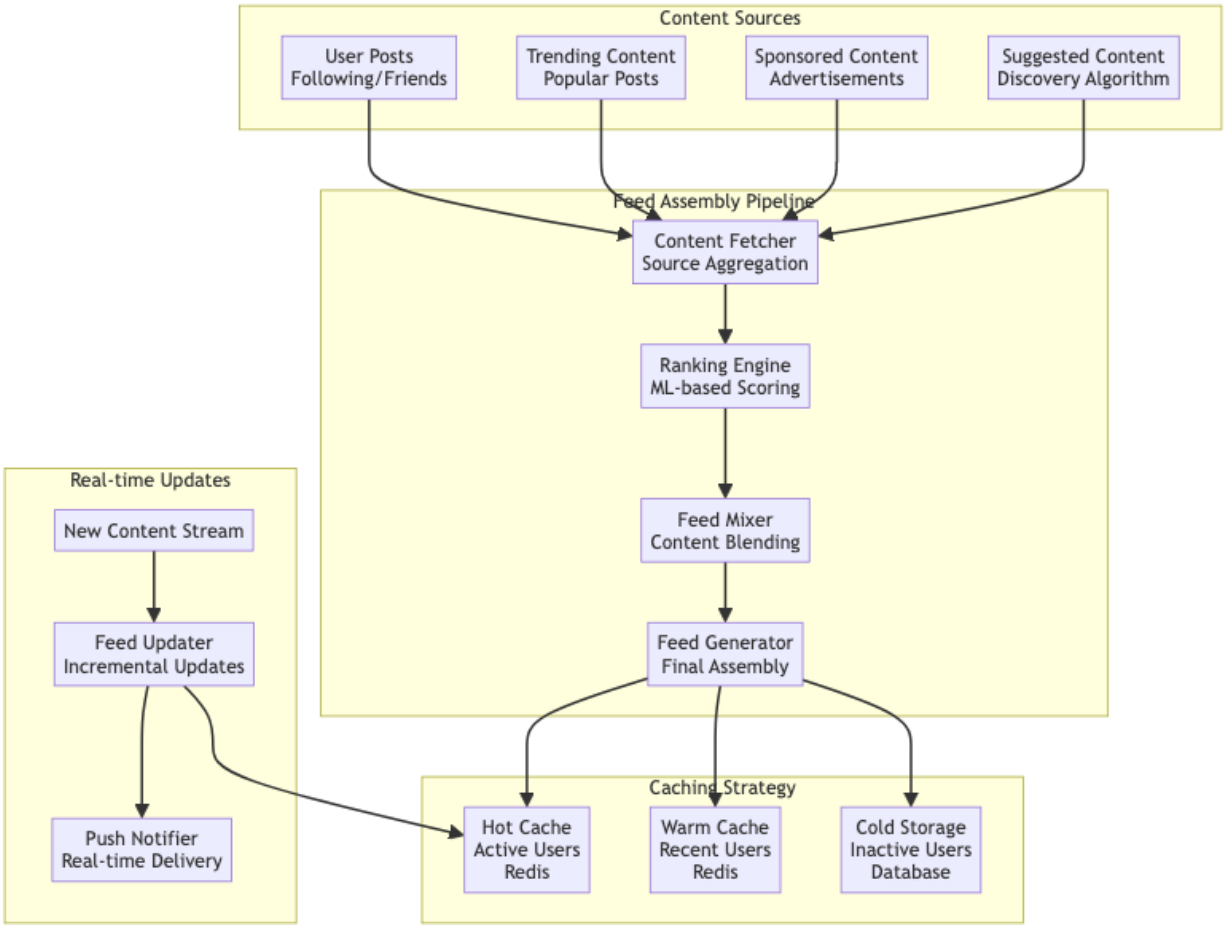

UI/UX and Component Structure

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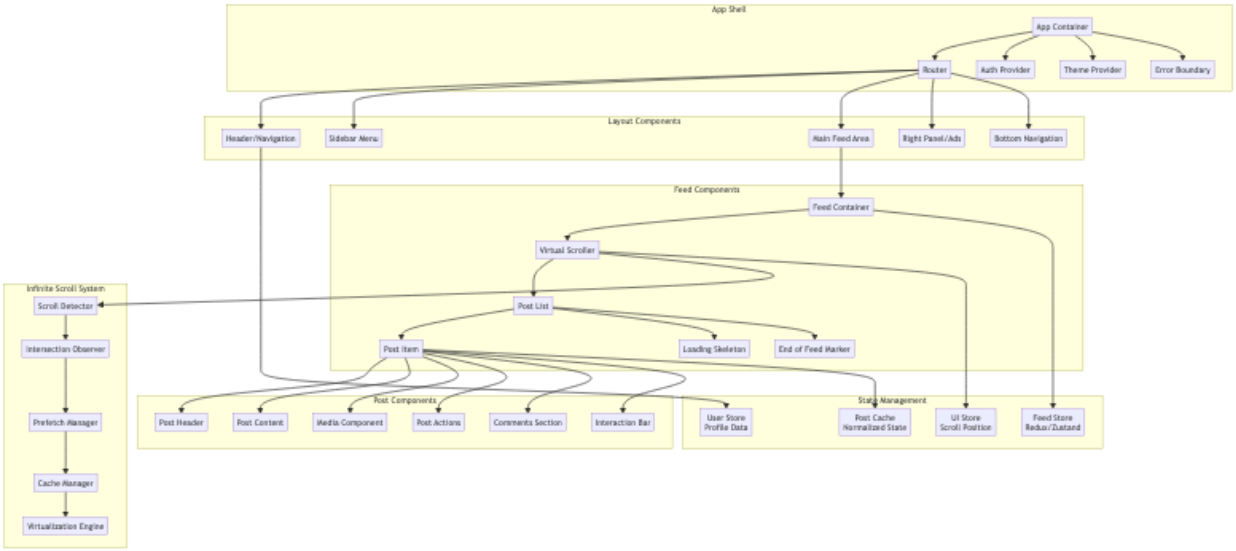

React Component Implementation ☐ Back to Top

FeedContainer.jsx

```jsx
import React, { useState, useEffect, useCallback, useRef } from 'react';
import { FeedProvider } from './FeedContext';
import VirtualScroller from './VirtualScroller';
import PostItem from './PostItem';
import LoadingSkeleton from './LoadingSkeleton';
import { useInfiniteQuery } from 'react-query';
import { useIntersectionObserver } from './hooks/useIntersectionObserver';

const FeedContainer = () => {
  const [posts, setPosts] = useState([]);
  const [hasNextPage, setHasNextPage] = useState(true);
  const loadMoreRef = useRef(null);
  const scrollPositionRef = useRef(0);

  const {
    data,
    fetchNextPage,
    hasNextPage: queryHasNextPage,
    isFetchingNextPage,
    isLoading,
    error
  } = useInfiniteQuery(
    'feed',
    ({ pageParam = null }) => fetchFeedPage(pageParam),
```

```
  {
    getNextPageParam: (lastPage) => lastPage.nextCursor,
    refetchOnWindowFocus: false,
    staleTime: 5 * 60 * 1000, // 5 minutes
  }
);

// Intersection Observer for infinite scroll
useIntersectionObserver(
  loadMoreRef,
  () => {
    if (queryHasNextPage && !isFetchingNextPage) {
      fetchNextPage();
    }
  },
  { threshold: 0.1 }
);

useEffect(() => {
  if (data) {
    const allPosts = data.pages.flatMap(page => page.posts);
    setPosts(allPosts);
    setHasNextPage(queryHasNextPage);
  }
}, [data, queryHasNextPage]);

const handleScroll = useCallback((scrollTop) => {
  scrollPositionRef.current = scrollTop;
}, []);

const updatePost = useCallback((postId, updates) => {
  setPosts(prev => prev.map(post =>
    post.id === postId ? { ...post, ...updates } : post
  ));
}, []);

const removePost = useCallback((postId) => {
  setPosts(prev => prev.filter(post => post.id !== postId));
}, []);

if (isLoading) {
  return <LoadingSkeleton count={5} />;
}

if (error) {
```

```
    return <div className="feed-error">Failed to load feed</div>;
  }

  return (
    <FeedProvider value={{
      posts,
      updatePost,
      removePost,
      isLoading: isFetchingNextPage
    }}>
      <div className="feed-container">
        <VirtualScroller
          items={posts}
          itemHeight={400}
          onScroll={handleScroll}
          renderItem={({ item, index, style }) => (
            <div style={style} key={item.id}>
              <PostItem post={item} index={index} />
            </div>
          )}
        />

        {/* Load more trigger */}
        <div
          ref={loadMoreRef}
          className="load-more-trigger"
          style={{ height: '20px', margin: '20px 0' }}
        >
          {isFetchingNextPage && <LoadingSkeleton count={2} />}
          {!queryHasNextPage && posts.length > 0 && (
            <div className="end-of-feed">You've reached the end!</div>
          )}
        </div>
      </div>
    </FeedProvider>
  );
};

// API function
const fetchFeedPage = async (cursor) => {
  const response = await fetch(`/api/feed?cursor=${cursor || ''}&limit=10`);
  return response.json();
};

export default FeedContainer;
```

VirtualScroller.jsx

```jsx
import React, { useState, useEffect, useRef, useMemo } from 'react';

const VirtualScroller = ({
  items,
  itemHeight,
  containerHeight = window.innerHeight,
  overscan = 5,
  onScroll,
  renderItem
}) => {
  const [scrollTop, setScrollTop] = useState(0);
  const [isScrolling, setIsScrolling] = useState(false);
  const scrollElementRef = useRef(null);
  const scrollTimeoutRef = useRef(null);

  const { visibleRange, totalHeight } = useMemo(() => {
    const containerTop = scrollTop;
    const containerBottom = containerTop + containerHeight;

    const startIndex = Math.max(0, Math.floor(containerTop / itemHeight) - overscan);
    const endIndex = Math.min(
      items.length - 1,
      Math.ceil(containerBottom / itemHeight) + overscan
    );

    return {
      visibleRange: { startIndex, endIndex },
      totalHeight: items.length * itemHeight
    };
  }, [scrollTop, containerHeight, itemHeight, items.length, overscan]);

  const visibleItems = useMemo(() => {
    const result = [];
    for (let i = visibleRange.startIndex; i <= visibleRange.endIndex; i++) {
      if (items[i]) {
        result.push({
          index: i,
          item: items[i],
          style: {
            position: 'absolute',
            top: i * itemHeight,
            width: '100%',
            height: itemHeight,
```

```
        }
      });
    }
  }
  return result;
}, [visibleRange, items, itemHeight]);

const handleScroll = (e) => {
  const newScrollTop = e.currentTarget.scrollTop;
  setScrollTop(newScrollTop);
  setIsScrolling(true);
  onScroll?.(newScrollTop);

  // Clear previous timeout
  if (scrollTimeoutRef.current) {
    clearTimeout(scrollTimeoutRef.current);
  }

  // Set scrolling to false after scroll ends
  scrollTimeoutRef.current = setTimeout(() => {
    setIsScrolling(false);
  }, 150);
};

return (
  <div
    ref={scrollElementRef}
    className="virtual-scroller"
    style={{
      height: containerHeight,
      overflow: 'auto',
      position: 'relative'
    }}
    onScroll={handleScroll}
  >
    <div
      className="virtual-scroller-content"
      style={{
        height: totalHeight,
        position: 'relative'
      }}
    >
      {visibleItems.map(({ index, item, style }) =>
        renderItem({ item, index, style })
      )}
```

```
      </div>
    </div>
  );
};

export default VirtualScroller;
```

PostItem.jsx

```
import React, { useState, useContext, memo } from 'react';
import { FeedContext } from './FeedContext';
import PostHeader from './PostHeader';
import PostContent from './PostContent';
import PostMedia from './PostMedia';
import PostActions from './PostActions';
import CommentsSection from './CommentsSection';

const PostItem = memo(({ post, index }) => {
  const { updatePost } = useContext(FeedContext);
  const [showComments, setShowComments] = useState(false);
  const [isVisible, setIsVisible] = useState(false);

  const handleLike = async () => {
    const newLikeStatus = !post.isLiked;
    const newLikeCount = post.likeCount + (newLikeStatus ? 1 : -1);

    // Optimistic update
    updatePost(post.id, {
      isLiked: newLikeStatus,
      likeCount: newLikeCount
    });

    try {
      await fetch(`/api/posts/${post.id}/like`, {
        method: newLikeStatus ? 'POST' : 'DELETE'
      });
    } catch (error) {
      // Revert on error
      updatePost(post.id, {
        isLiked: !newLikeStatus,
        likeCount: post.likeCount
      });
    }
  };

  const handleShare = () => {
```

```
  if (navigator.share) {
    navigator.share({
      title: `Post by ${post.author.name}`,
      url: `/posts/${post.id}`
    });
  } else {
    navigator.clipboard.writeText(`${window.location.origin}/posts/${post.id}`);
  }
};

const handleComment = () => {
  setShowComments(!showComments);
};

return (
  <article className="post-item" data-post-id={post.id}>
    <PostHeader
      author={post.author}
      timestamp={post.createdAt}
      isFollowing={post.author.isFollowing}
    />

    <PostContent
      content={post.content}
      hashtags={post.hashtags}
      mentions={post.mentions}
    />

    {post.media && post.media.length > 0 && (
      <PostMedia
        media={post.media}
        onVisibilityChange={setIsVisible}
      />
    )}

    <PostActions
      likeCount={post.likeCount}
      commentCount={post.commentCount}
      shareCount={post.shareCount}
      isLiked={post.isLiked}
      isBookmarked={post.isBookmarked}
      onLike={handleLike}
      onComment={handleComment}
      onShare={handleShare}
    />
```

```
      {showComments && (
        <CommentsSection
          postId={post.id}
          comments={post.comments}
          onCommentAdd={(comment) => {
            updatePost(post.id, {
              commentCount: post.commentCount + 1,
              comments: [...(post.comments || []), comment]
            });
          }}
        />
      )}
    </article>
  );
});

export default PostItem;
```

Infinite Scroll Hook

```
// hooks/useInfiniteScroll.js
import { useEffect, useCallback, useRef } from 'react';

export const useInfiniteScroll = ({
  hasNextPage,
  fetchNextPage,
  isFetchingNextPage,
  threshold = 300
}) => {
  const sentinelRef = useRef(null);

  const handleIntersection = useCallback((entries) => {
    const [entry] = entries;
    if (entry.isIntersecting && hasNextPage && !isFetchingNextPage) {
      fetchNextPage();
    }
  }, [hasNextPage, fetchNextPage, isFetchingNextPage]);

  useEffect(() => {
    const sentinel = sentinelRef.current;
    if (!sentinel) return;

    const observer = new IntersectionObserver(handleIntersection, {
      rootMargin: `${threshold}px`,
      threshold: 0.1
```

```
    });

    observer.observe(sentinel);

    return () => {
      observer.unobserve(sentinel);
      observer.disconnect();
    };
  }, [handleIntersection, threshold]);

  return sentinelRef;
};

// hooks/useVirtualization.js
import { useMemo } from 'react';

export const useVirtualization = ({
  items,
  itemHeight,
  containerHeight,
  scrollTop,
  overscan = 5
}) => {
  return useMemo(() => {
    const startIndex = Math.max(
      0,
      Math.floor(scrollTop / itemHeight) - overscan
    );

    const endIndex = Math.min(
      items.length - 1,
      Math.ceil((scrollTop + containerHeight) / itemHeight) + overscan
    );

    const visibleItems = [];
    for (let i = startIndex; i <= endIndex; i++) {
      if (items[i]) {
        visibleItems.push({
          index: i,
          data: items[i],
          offsetTop: i * itemHeight
        });
      }
    }
```

```
    return {
      startIndex,
      endIndex,
      visibleItems,
      totalHeight: items.length * itemHeight
    };
  }, [items, itemHeight, containerHeight, scrollTop, overscan]);
};

// Feed Performance Optimization
export const useFeedOptimization = () => {
  const preloadImages = useCallback((posts) => {
    posts.forEach(post => {
      if (post.media) {
        post.media.forEach(media => {
          if (media.type === 'image') {
            const img = new Image();
            img.src = media.thumbnailUrl || media.url;
          }
        });
      }
    });
  }, []);

  const lazyLoadMedia = useCallback((element, mediaSrc) => {
    const observer = new IntersectionObserver((entries) => {
      entries.forEach(entry => {
        if (entry.isIntersecting) {
          const img = entry.target;
          img.src = mediaSrc;
          img.onload = () => {
            img.classList.add('loaded');
          };
          observer.unobserve(img);
        }
      });
    });

    observer.observe(element);
    return () => observer.disconnect();
  }, []);

  return { preloadImages, lazyLoadMedia };
};
```

Virtual Scrolling Implementation

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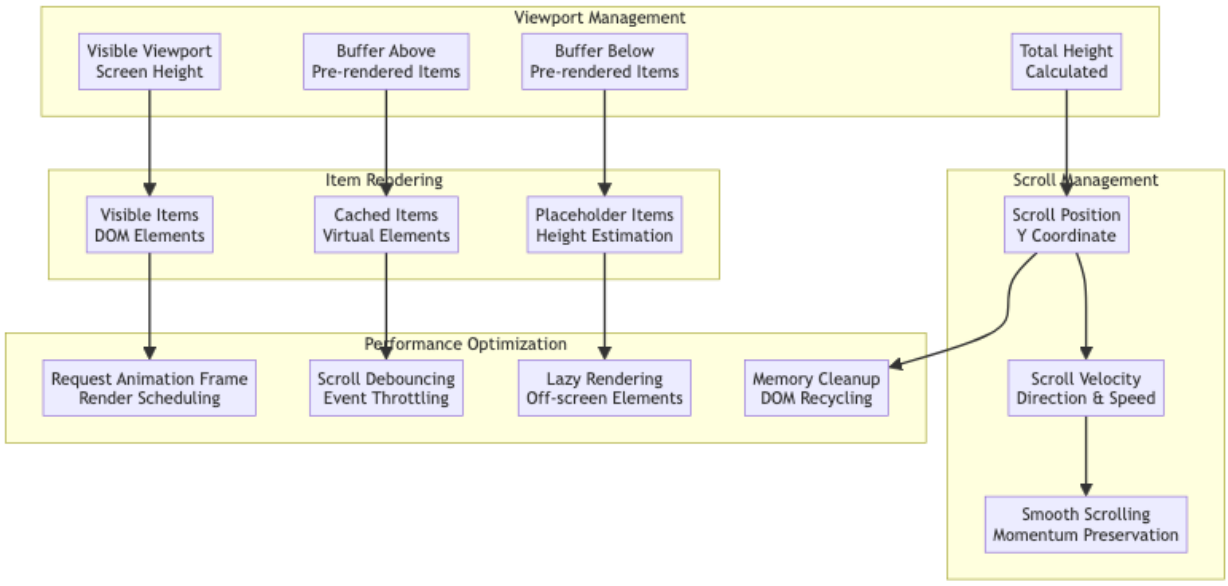

Responsive Feed Layout

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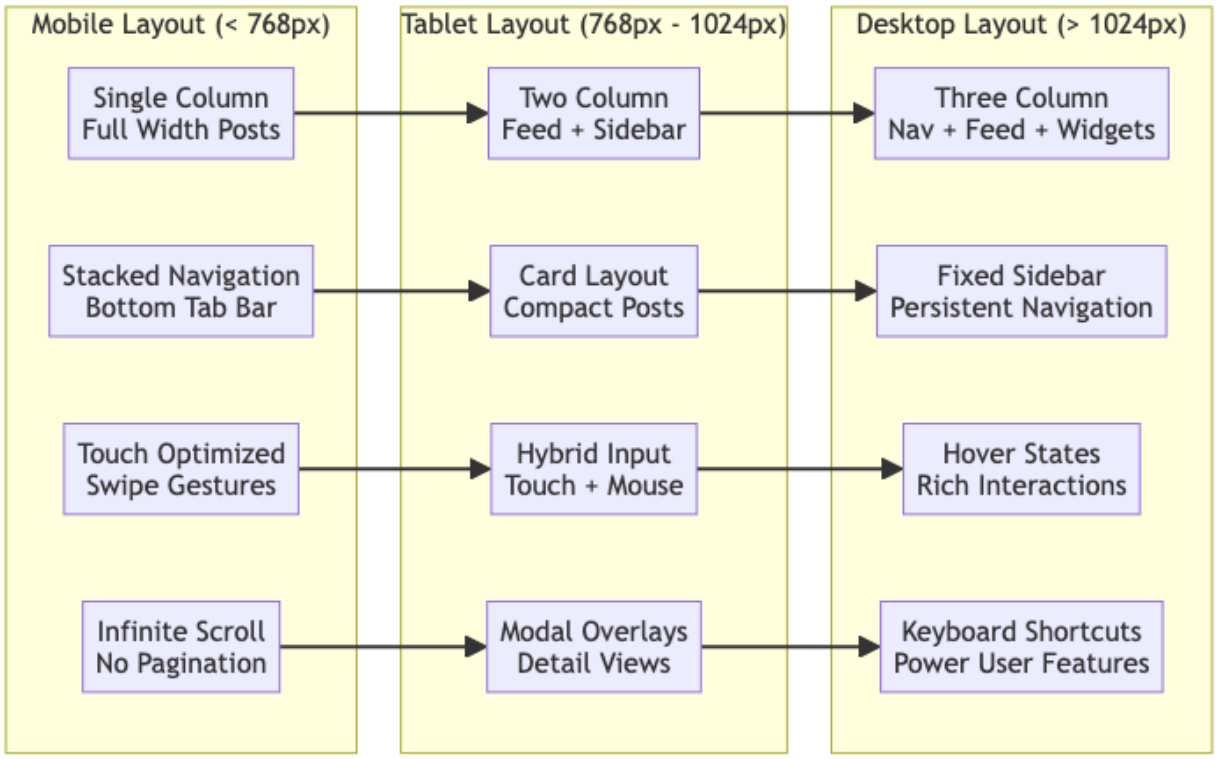

Real-Time Sync, Data Modeling & APIs

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Content Ranking Algorithm

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ML-Based Feed Ranking

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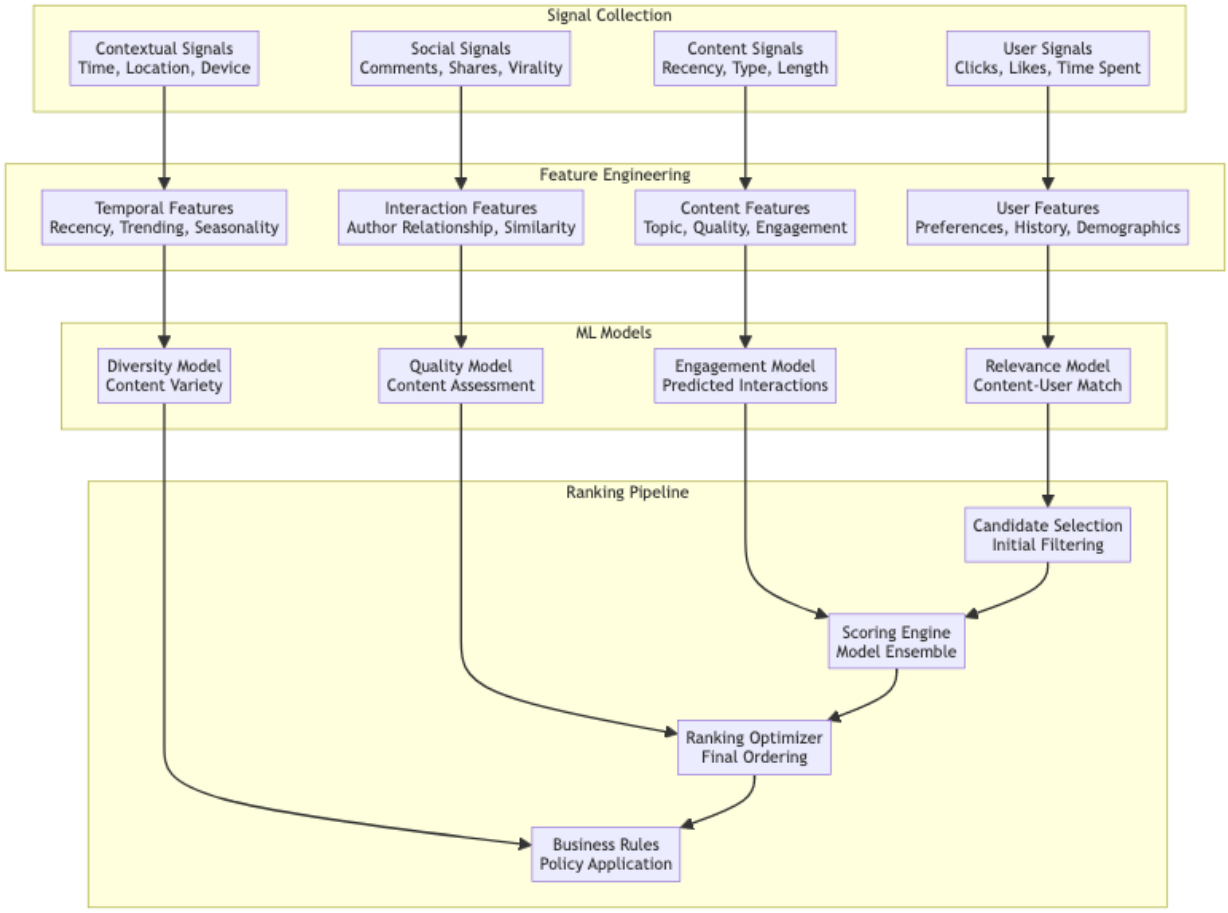

Feed Generation Algorithm □ Back to Top

Multi-Stage Ranking Process:

1. **Candidate Generation** (10K □ 1K posts):
   - Following/Friends posts (80%)
   - Popular content (15%)
   - Sponsored content (5%)
2. **Initial Ranking** (1K □ 500 posts):
   - Relevance scoring
   - Recency weighting
   - Content quality filtering
3. **Final Ranking** (500 □ 100 posts):
   - Engagement prediction
   - Diversity injection
   - Business rule application

Infinite Scroll Implementation

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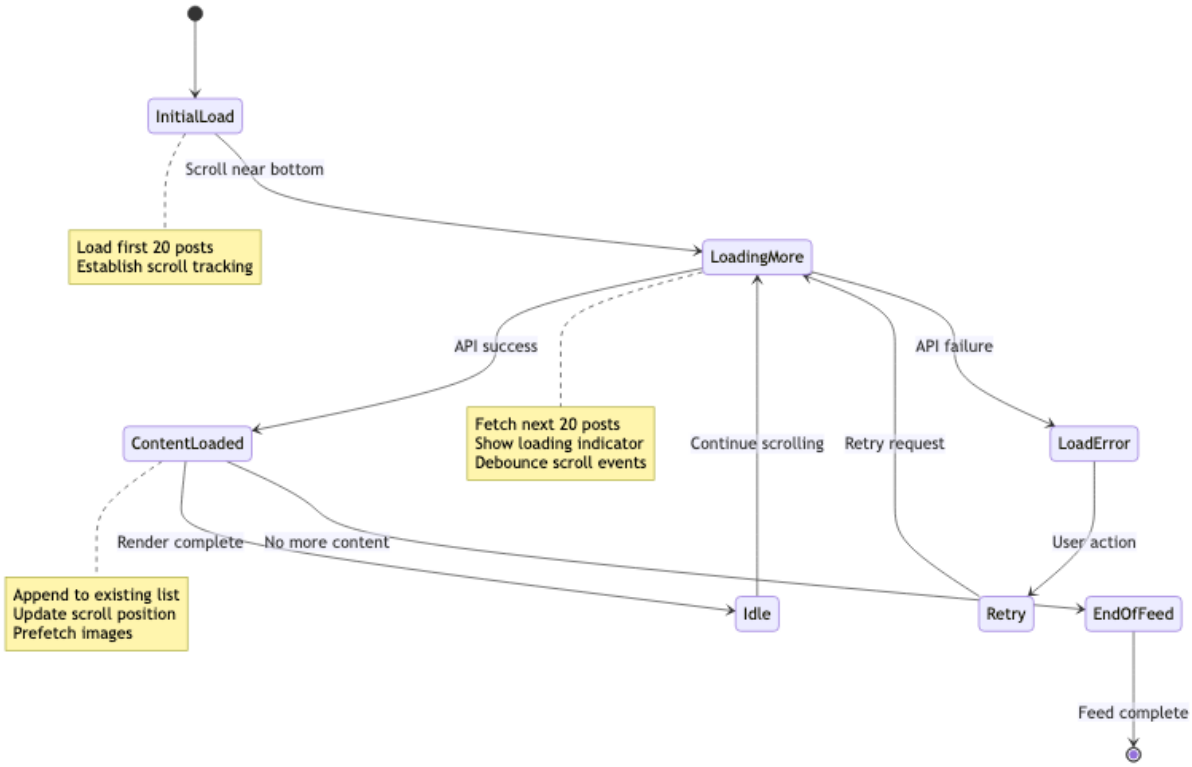
Pagination Strategy Back to Top



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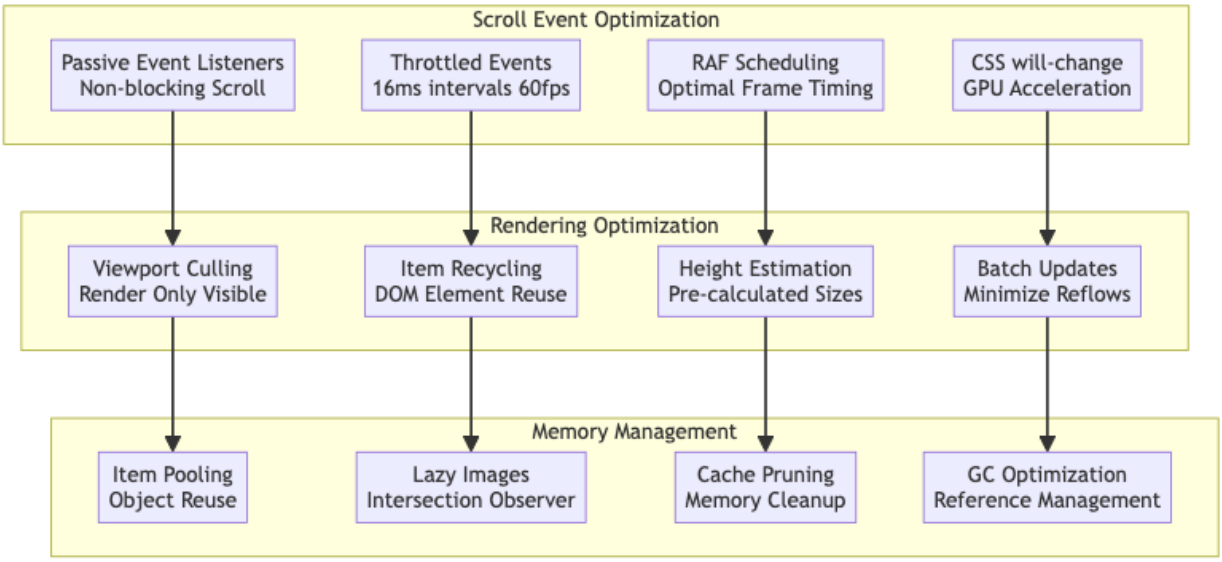
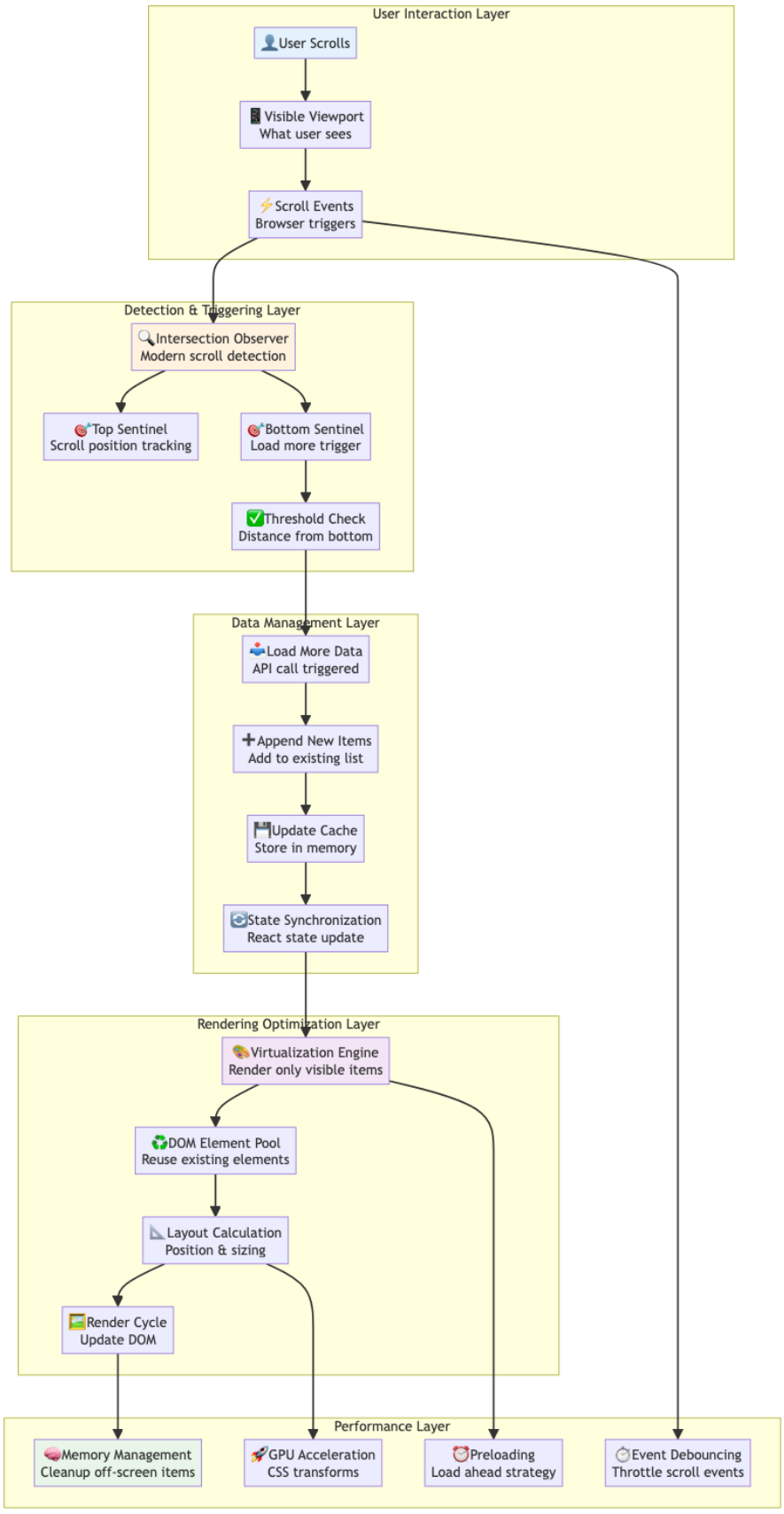


Advanced Infinite Scroll Techniques □ Back to Top

Bird's Eye View: How Infinite Scroll Works Before diving into implementation details, let's understand the high-level architecture and flow of modern infinite scrolling systems.

Core Concept: Instead of loading all content at once, we dynamically load content as the user scrolls, while maintaining optimal performance through virtualization and efficient DOM management.


User Interaction Layer
User Scrolls
Visible Viewport
What user sees
Scroll Events
Browser triggers
Detection & Triggering Layer
Intersection Observer
Modern scroll detection
Top Sentinel
Scroll position tracking
Bottom Sentinel
Load more trigger
Threshold Check
Distance from bottom
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Load More Data
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Update Cache
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State Synchronization
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Rendering Optimization Layer
Virtualization Engine
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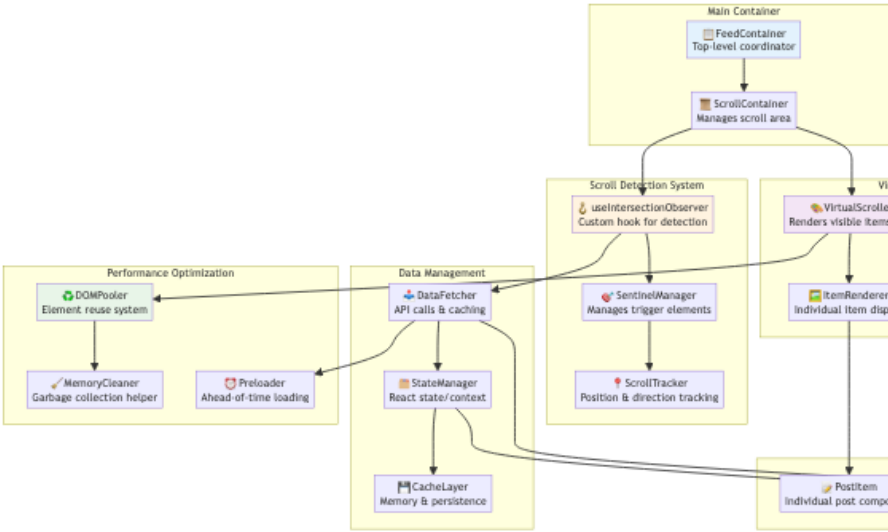
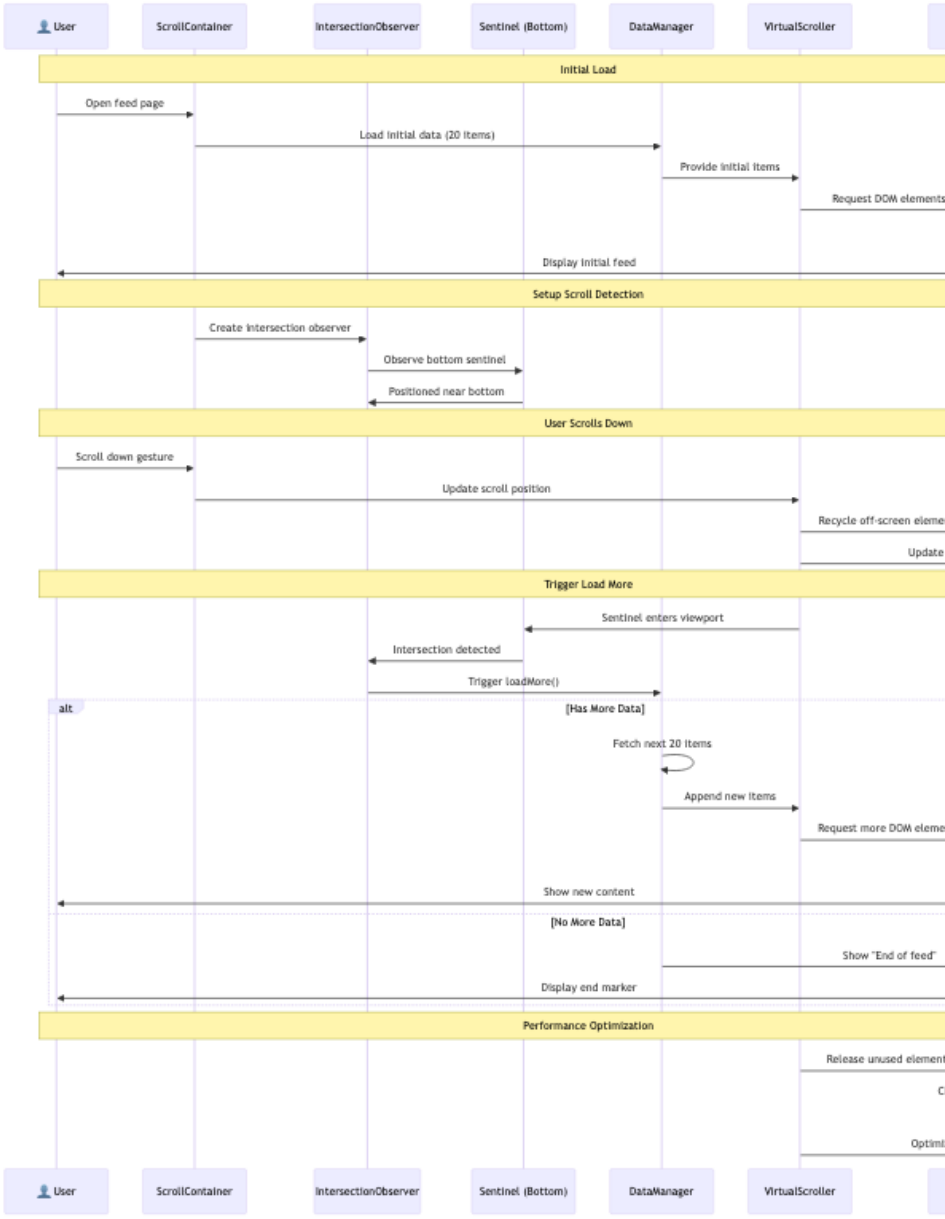
DOM Element Pool
Reuse existing elements
Layout Calculation
Position & sizing
Render Cycle
Update DOM
Performance Layer
Memory Management
Cleanup off-screen items
GPU Acceleration
CSS transforms
Preloading
Load ahead strategy
Event Debouncing
Throttle scroll events

Component Architecture Overview





Infinite Scroll Flow Sequence

Key Performance Strategies

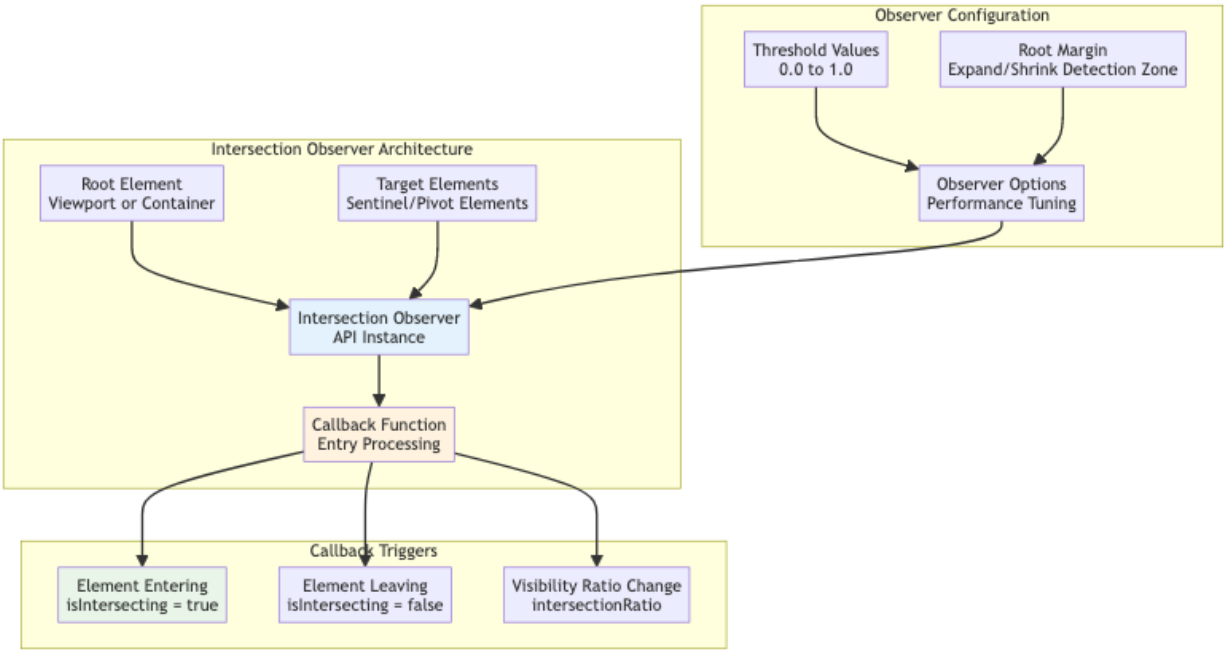
How It All Works Together:

1. **User scrolls** → Browser fires scroll events
2. **Intersection Observer** detects when sentinel elements enter viewport (more efficient than scroll listeners)
3. **Sentinel elements** (invisible markers) trigger actions when they become visible
4. **Data fetcher** loads more content when bottom sentinel is reached
5. **Virtual scroller** only renders items currently visible in viewport
6. **DOM pool** reuses existing elements instead of creating/destroying them
7. **Memory manager** cleans up off-screen content to prevent memory leaks
8. **Performance optimizations** ensure smooth 60fps scrolling experience

This architecture provides: - ✅ **Smooth Performance**: 60fps scrolling even with thousands of items - ✅ **Memory Efficiency**: Constant memory usage regardless of list size - ✅ **Battery Friendly**: Minimal CPU usage through optimized detection - ✅ **Responsive UX**: Immediate feedback and progressive loading - ✅ **Scalable**: Handles millions of items without performance degradation

Intersection Observer API for Scroll Detection The **Intersection Observer API** is the modern, performant way to detect when elements enter or leave the viewport. It's essential for infinite scrolling as it eliminates the need for scroll event listeners, reducing performance overhead.

Key Benefits: - **Asynchronous**: Doesn't block the main thread - **Efficient**: Browser-optimized for visibility detection - **Precise**: Configurable thresholds and root margins - **Battery-friendly**: Lower CPU usage compared to scroll events



React Implementation with Intersection Observer:

```
// hooks/useIntersectionObserver.js
import { useEffect, useRef, useCallback } from 'react';

export const useIntersectionObserver = (
  callback,
  options = {}
) => {
  const targetRef = useRef(null);
  const observerRef = useRef(null);

  const {
    threshold = 0.1,
    rootMargin = '100px',
    root = null,
    enabled = true
  } = options;

  const handleIntersection = useCallback((entries) => {
    entries.forEach(entry => {
      if (entry.isIntersecting) {
        callback(entry);
      }
    });
  }, [callback]);
```

```
  useEffect(() => {
    if (!enabled || !targetRef.current) return;

    // Create observer with optimized settings
    observerRef.current = new IntersectionObserver(
      handleIntersection,
      {
        threshold,
        rootMargin,
        root
      }
    );

    const target = targetRef.current;
    observerRef.current.observe(target);

    // Cleanup function
    return () => {
      if (observerRef.current && target) {
        observerRef.current.unobserve(target);
        observerRef.current.disconnect();
      }
    };
  }, [handleIntersection, threshold, rootMargin, root, enabled]);

  return targetRef;
};

// Enhanced hook for infinite scroll
export const useInfiniteScrollObserver = ({
  hasNextPage,
  isFetchingNextPage,
  fetchNextPage,
  threshold = 0.1,
  rootMargin = '200px'
}) => {
  const loadMoreCallback = useCallback((entry) => {
    // Only trigger if we have more data and aren't already loading
    if (hasNextPage && !isFetchingNextPage) {
      console.log('Loading more content...', {
        intersectionRatio: entry.intersectionRatio,
        boundingRect: entry.boundingClientRect
      });
      fetchNextPage();
    }
```

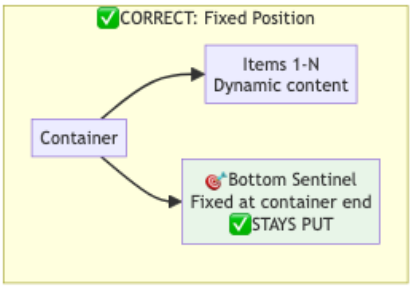
```
  }, [hasNextPage, isFetchingNextPage, fetchNextPage]);

  const sentinelRef = useIntersectionObserver(
    loadMoreCallback,
    { threshold, rootMargin }
  );

  return sentinelRef;
};
```

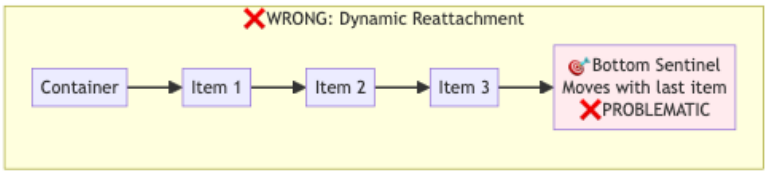
Pivot Elements (Sentinel/Trigger/Anchor Elements) **Pivot elements**, also known as **sentinel elements**, **trigger elements**, **scroll anchors**, or **waypoint elements**, are invisible or minimal DOM elements strategically placed to detect scroll boundaries and trigger actions.

Common Names and Use Cases: - **Sentinel Elements**: Guard elements that watch for boundary crossings - **Trigger Elements**: Elements that trigger loading actions - **Scroll Anchors**: Elements that anchor scroll position calculations - **Waypoint Elements**: Navigation milestone elements - **Load More Triggers**: Specific to pagination/infinite scroll - **Intersection Targets**: Elements targeted by Intersection Observer

□ **Sentinel Element Positioning: Fixed vs Dynamic** **Key Question**: Are sentinel elements reattached to the last element when new content is added?

Answer: **No, they remain in fixed positions!** Here's why and how:





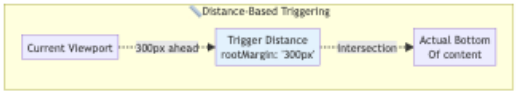
Why Fixed Position is Better:

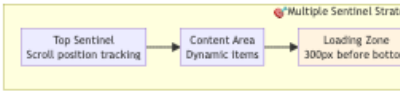
1. **Performance**: No DOM manipulation when adding items
2. **Reliability**: Sentinel is always detectable by Intersection Observer
3. **Simplicity**: No complex reattachment logic needed
4. **Consistency**: Trigger behavior remains predictable

```
//  WRONG: Moving sentinel approach (problematic)
const WrongSentinelApproach = ({ items, loadMore }) => {
  return (
    <div className="container">
      {items.map((item, index) => (
```

```
        <div key={item.id}>
          {/* Regular item */}
          <PostItem item={item} />

          {/*  Sentinel attached to last item - PROBLEMATIC */}
          {index === items.length - 1 && (
            <div ref={sentinelRef} className="bottom-sentinel" />
          )}
        </div>
      ))}
    </div>
  );
};

//  CORRECT: Fixed sentinel approach
const CorrectSentinelApproach = ({ items, loadMore, hasMore, isLoading }) => {
  const bottomSentinelRef = useInfiniteScrollObserver({
    hasNextPage: hasMore,
    isFetchingNextPage: isLoading,
    fetchNextPage: loadMore,
    rootMargin: '200px'
  });

  return (
    <div className="container">
      {/* Dynamic content area */}
      <div className="items-container">
        {items.map((item) => (
          <PostItem key={item.id} item={item} />
        ))}
      </div>

      {/*  Fixed sentinel at container bottom */}
      <div
        ref={bottomSentinelRef}
        className="bottom-sentinel"
        style={{
          height: '20px',
          visibility: hasMore ? 'visible' : 'hidden'
        }}
      >
        {isLoading && <LoadingSpinner />}
      </div>
    </div>
  );
```

```
};
```





Sentinel Positioning Strategies

Advanced Implementation with Multiple Sentinels:

```
// Enhanced implementation with multiple fixed sentinels
const AdvancedInfiniteScroll = ({
  items,
  loadMore,
  hasMore,
  isLoading,
  onScrollTop
}) => {
  // Top sentinel for "scroll to top" detection
  const topSentinelRef = useIntersectionObserver(
    (entry) => {
      if (entry.isIntersecting) {
        onScrollTop?.(); // User scrolled back to top
      }
    },
    { threshold: 1.0 }
  );

  // Bottom sentinel for loading more content
  const bottomSentinelRef = useInfiniteScrollObserver({
    hasNextPage: hasMore,
    isFetchingNextPage: isLoading,
    fetchNextPage: loadMore,
    threshold: 0.1,
    rootMargin: '300px' // Start loading 300px before reaching sentinel
  });

  // Middle sentinel for analytics/tracking
  const midSentinelRef = useIntersectionObserver(
    (entry) => {
      // Track user engagement - they've scrolled halfway
      analytics.track('feed_midpoint_reached', {
        itemCount: items.length,
        timestamp: Date.now()
      });
    },
    { threshold: 0.5 }
  );
```

```
return (
  <div className="infinite-scroll-container">
    {/* Fixed top sentinel */}
    <div
      ref={topSentinelRef}
      className="top-sentinel"
      style={{ height: '1px', position: 'absolute', top: 0 }}
      data-testid="top-sentinel"
    />

    {/* Dynamic content */}
    <div className="content-area">
      {items.map((item, index) => (
        <div key={item.id}>
          <PostItem item={item} />

          {/* Mid-point tracking sentinel (appears once) */}
          {index === Math.floor(items.length / 2) && (
            <div
              ref={midSentinelRef}
              className="mid-sentinel"
              style={{ height: '1px' }}
              data-testid="mid-sentinel"
            />
          )}
        </div>
      ))}
    </div>

    {/* Fixed bottom sentinel - NEVER moves */}
    <div
      ref={bottomSentinelRef}
      className="bottom-sentinel"
      style={{
        height: '50px',
        display: 'flex',
        alignItems: 'center',
        justifyContent: 'center',
        margin: '20px 0'
      }}
      data-testid="bottom-sentinel"
    >
      {isLoading && (
        <div className="loading-state">
```

```
            <LoadingSpinner />
            <span>Loading more posts...</span>
          </div>
        )}

        {!hasMore && items.length > 0 && (
          <div className="end-state">
              You've reached the end!
          </div>
        )}
      </div>
    </div>
  );
};
```

Real-World Sentinel Management

```
// Production-ready sentinel management
const useSentinelManager = () => {
  const sentinelsRef = useRef(new Map());

  const createSentinel = useCallback((id, config) => {
    const {
      position = 'bottom',
      rootMargin = '100px',
      threshold = 0.1,
      callback
    } = config;

    const sentinelElement = document.createElement('div');
    sentinelElement.className = `sentinel-${position}`;
    sentinelElement.style.cssText = `
      height: 1px;
      pointer-events: none;
      ${position === 'top' ? 'position: absolute; top: 0;' : ''}
    `;

    const observer = new IntersectionObserver(
      (entries) => {
        entries.forEach(entry => {
          if (entry.isIntersecting) {
            callback(entry);
          }
        });
      },
```

```
    { rootMargin, threshold }
  );

  observer.observe(sentinelElement);

  sentinelsRef.current.set(id, {
    element: sentinelElement,
    observer,
    config
  });

  return sentinelElement;
}, []);

const removeSentinel = useCallback((id) => {
  const sentinel = sentinelsRef.current.get(id);
  if (sentinel) {
    sentinel.observer.disconnect();
    if (sentinel.element.parentNode) {
      sentinel.element.parentNode.removeChild(sentinel.element);
    }
    sentinelsRef.current.delete(id);
  }
}, []);

const updateSentinel = useCallback((id, newConfig) => {
  removeSentinel(id);
  return createSentinel(id, newConfig);
}, [createSentinel, removeSentinel]);

// Cleanup on unmount
useEffect(() => {
  return () => {
    sentinelsRef.current.forEach((sentinel) => {
      sentinel.observer.disconnect();
    });
    sentinelsRef.current.clear();
  };
}, []);

return {
  createSentinel,
  removeSentinel,
  updateSentinel,
  getSentinelCount: () => sentinelsRef.current.size
```

```
  };
};
```

Key Takeaways:

1. **Sentinels Stay Fixed** - They don't move when content updates
2. **Container-Relative** - Positioned relative to the scroll container, not content
3. **Performance Benefit** - No DOM manipulation overhead when adding items
4. **Predictable Behavior** - Always triggers at the same relative position
5. **Multiple Sentinels** - Can have top, middle, and bottom sentinels for different purposes

This approach ensures consistent, performant infinite scrolling behavior that scales well with large datasets.

```jsx
// InfiniteScrollContainer.jsx
import React, { useState, useEffect, useCallback } from 'react';
import { useInfiniteScrollObserver } from '../hooks/useIntersectionObserver';
import { useVirtualization } from '../hooks/useVirtualization';

const InfiniteScrollContainer = ({
  items = [],
  loadMore,
  hasMore = true,
  isLoading = false,
  renderItem,
  estimatedItemHeight = 200,
  overscan = 5
}) => {
  const [scrollTop, setScrollTop] = useState(0);
  const [containerHeight, setContainerHeight] = useState(600);

  // Multiple sentinel elements for different purposes
  const bottomSentinelRef = useInfiniteScrollObserver({
    hasNextPage: hasMore,
    isFetchingNextPage: isLoading,
    fetchNextPage: loadMore,
    threshold: 0.1,
    rootMargin: '300px' // Start loading 300px before reaching the element
  });

  const topSentinelRef = useInfiniteScrollObserver({
    hasNextPage: false, // Used for scroll position tracking, not loading
    isFetchingNextPage: false,
    fetchNextPage: () => {},
    threshold: 1.0,
    rootMargin: '0px'
```

```
});

// Virtualization for performance
const { visibleItems, totalHeight, startIndex, endIndex } = useVirtualization({
  items,
  itemHeight: estimatedItemHeight,
  containerHeight,
  scrollTop,
  overscan
});

const handleScroll = useCallback((e) => {
  const newScrollTop = e.target.scrollTop;
  setScrollTop(newScrollTop);

  // Optional: Throttle for better performance
  requestAnimationFrame(() => {
    // Additional scroll handling logic
  });
}, []);

useEffect(() => {
  // Set up container height observer
  const resizeObserver = new ResizeObserver(entries => {
    const [entry] = entries;
    setContainerHeight(entry.contentRect.height);
  });

  const container = document.getElementById('scroll-container');
  if (container) {
    resizeObserver.observe(container);
  }

  return () => resizeObserver.disconnect();
}, []);

return (
  <div
    id="scroll-container"
    className="infinite-scroll-container"
    style={{
      height: '100vh',
      overflow: 'auto',
      position: 'relative'
    }}
```

```
  onScroll={handleScroll}
>
  {/* Top Sentinel - for scroll position tracking */}
  <div
    ref={topSentinelRef}
    className="sentinel-top"
    style={{
      height: '1px',
      position: 'absolute',
      top: 0,
      width: '100%',
      pointerEvents: 'none'
    }}
    data-testid="top-sentinel"
  />

  {/* Virtualized content container */}
  <div
    className="content-container"
    style={{
      height: totalHeight,
      position: 'relative'
    }}
  >
    {visibleItems.map(({ index, data, offsetTop }) => (
      <div
        key={data.id || index}
        style={{
          position: 'absolute',
          top: offsetTop,
          width: '100%',
          height: estimatedItemHeight
        }}
      >
        {renderItem({ item: data, index })}
      </div>
    ))}
  </div>

  {/* Bottom Sentinel - for loading more content */}
  <div
    ref={bottomSentinelRef}
    className="sentinel-bottom"
    style={{
      height: '20px',
```

```
            marginTop: '10px',
            display: 'flex',
            alignItems: 'center',
            justifyContent: 'center',
            visibility: hasMore ? 'visible' : 'hidden'
          }}
          data-testid="bottom-sentinel"
        >
          {isLoading && (
            <div className="loading-indicator">
              <span>Loading more content...</span>
            </div>
          )}
        </div>

        {/* End of content marker */}
        {!hasMore && items.length > 0 && (
          <div className="end-of-content" style={{
            padding: '20px',
            textAlign: 'center',
            color: '#666'
          }}>
            You've reached the end!
          </div>
        )}
      </div>
    );
};

export default InfiniteScrollContainer;
```

DOM Element Reuse and Object Pooling DOM element reuse is crucial for performance in infinite scroll. Instead of creating/destroying DOM nodes constantly, we maintain a pool of elements and reuse them.

```
// hooks/useElementPool.js
import { useRef, useCallback } from 'react';

export const useElementPool = (initialSize = 10) => {
  const poolRef = useRef({
    available: [],
    inUse: new Map(),
    total: 0
  });
```

```
const createElement = useCallback((type = 'div', className = '') => {
  const element = document.createElement(type);
  if (className) element.className = className;
  return element;
}, []);

const getElement = useCallback((id, type = 'div', className = '') => {
  const pool = poolRef.current;

  // Return existing element if already in use
  if (pool.inUse.has(id)) {
    return pool.inUse.get(id);
  }

  let element;

  // Reuse from pool if available
  if (pool.available.length > 0) {
    element = pool.available.pop();
    // Reset element properties
    element.className = className;
    element.innerHTML = '';
    element.style.cssText = '';
  } else {
    // Create new element if pool is empty
    element = createElement(type, className);
    pool.total++;
  }

  pool.inUse.set(id, element);
  return element;
}, [createElement]);

const releaseElement = useCallback((id) => {
  const pool = poolRef.current;
  const element = pool.inUse.get(id);

  if (element) {
    pool.inUse.delete(id);

    // Clean up element before returning to pool
    element.innerHTML = '';
    element.className = '';
    element.style.cssText = '';
```

```
      // Add back to available pool
      pool.available.push(element);
    }
  }, []);

  const getPoolStats = useCallback(() => {
    const pool = poolRef.current;
    return {
      total: pool.total,
      inUse: pool.inUse.size,
      available: pool.available.length
    };
  }, []);

  return {
    getElement,
    releaseElement,
    getPoolStats
  };
};

// VirtualizedList.jsx - Advanced implementation with element pooling
import React, { useState, useEffect, useRef, useCallback } from 'react';
import { useElementPool } from '../hooks/useElementPool';

const VirtualizedList = ({
  items,
  itemHeight,
  containerHeight,
  renderItem,
  overscan = 3
}) => {
  const [scrollTop, setScrollTop] = useState(0);
  const containerRef = useRef(null);
  const { getElement, releaseElement, getPoolStats } = useElementPool();
  const renderedItemsRef = useRef(new Map());

  // Calculate visible range
  const getVisibleRange = useCallback(() => {
    const startIndex = Math.floor(scrollTop / itemHeight);
    const endIndex = Math.min(
      Math.ceil((scrollTop + containerHeight) / itemHeight),
      items.length - 1
    );
```

```
    return {
      start: Math.max(0, startIndex - overscan),
      end: Math.min(items.length - 1, endIndex + overscan)
    };
  }, [scrollTop, itemHeight, containerHeight, items.length, overscan]);

  const renderVisibleItems = useCallback(() => {
    const { start, end } = getVisibleRange();
    const container = containerRef.current;
    if (!container) return;

    // Track which items should be visible
    const shouldBeVisible = new Set();
    for (let i = start; i <= end; i++) {
      shouldBeVisible.add(i);
    }

    // Remove items that are no longer visible
    for (const [index, element] of renderedItemsRef.current) {
      if (!shouldBeVisible.has(index)) {
        if (element.parentNode) {
          element.parentNode.removeChild(element);
        }
        releaseElement(index);
        renderedItemsRef.current.delete(index);
      }
    }

    // Add/update visible items
    for (let i = start; i <= end; i++) {
      if (!renderedItemsRef.current.has(i)) {
        const element = getElement(i, 'div', 'list-item');

        // Set position and size
        element.style.position = 'absolute';
        element.style.top = `${i * itemHeight}px`;
        element.style.width = '100%';
        element.style.height = `${itemHeight}px`;

        // Render content
        const itemData = items[i];
        if (itemData) {
          element.innerHTML = renderItem(itemData, i);
        }
```

```
        container.appendChild(element);
        renderedItemsRef.current.set(i, element);
      }
    }

    // Debug: Log pool stats occasionally
    if (Math.random() < 0.01) { // 1% chance
      console.log('Element Pool Stats:', getPoolStats());
    }
  }, [getVisibleRange, getElement, releaseElement, getPoolStats, items, itemHeight, rend

  const handleScroll = useCallback((e) => {
    const newScrollTop = e.target.scrollTop;
    setScrollTop(newScrollTop);
  }, []);

  // Update rendered items when scroll position or data changes
  useEffect(() => {
    renderVisibleItems();
  }, [renderVisibleItems]);

  // Cleanup on unmount
  useEffect(() => {
    return () => {
      // Release all elements back to pool
      for (const [index] of renderedItemsRef.current) {
        releaseElement(index);
      }
      renderedItemsRef.current.clear();
    };
  }, [releaseElement]);

  const totalHeight = items.length * itemHeight;

  return (
    <div
      ref={containerRef}
      className="virtualized-list"
      style={{
        height: containerHeight,
        overflow: 'auto',
        position: 'relative'
      }}
      onScroll={handleScroll}
    >
```

```
      <div
        style={{
          height: totalHeight,
          position: 'relative'
        }}
      />
    </div>
  );
};

export default VirtualizedList;
```

Advanced Scroll Position Management

```
// hooks/useScrollPosition.js
import { useState, useEffect, useRef, useCallback } from 'react';

export const useScrollPosition = (elementRef) => {
  const [scrollPosition, setScrollPosition] = useState({
    x: 0,
    y: 0,
    direction: null,
    isScrolling: false
  });

  const lastScrollTop = useRef(0);
  const scrollTimeoutRef = useRef(null);

  const handleScroll = useCallback(() => {
    if (!elementRef.current) return;

    const element = elementRef.current;
    const currentScrollTop = element.scrollTop;
    const currentScrollLeft = element.scrollLeft;

    // Determine scroll direction
    let direction = null;
    if (currentScrollTop > lastScrollTop.current) {
      direction = 'down';
    } else if (currentScrollTop < lastScrollTop.current) {
      direction = 'up';
    }

    setScrollPosition({
      x: currentScrollLeft,
```

```
      y: currentScrollTop,
      direction,
      isScrolling: true
    });

    lastScrollTop.current = currentScrollTop;

    // Clear existing timeout
    if (scrollTimeoutRef.current) {
      clearTimeout(scrollTimeoutRef.current);
    }

    // Set scrolling to false after scroll ends
    scrollTimeoutRef.current = setTimeout(() => {
      setScrollPosition(prev => ({
        ...prev,
        isScrolling: false
      }));
    }, 150);
  }, [elementRef]);

  useEffect(() => {
    const element = elementRef.current;
    if (!element) return;

    // Use passive listener for better performance
    element.addEventListener('scroll', handleScroll, { passive: true });

    return () => {
      element.removeEventListener('scroll', handleScroll);
      if (scrollTimeoutRef.current) {
        clearTimeout(scrollTimeoutRef.current);
      }
    };
  }, [handleScroll]);

  return scrollPosition;
};

// Component usage example
const OptimizedInfiniteScroll = () => {
  const containerRef = useRef(null);
  const scrollPosition = useScrollPosition(containerRef);

  const sentinelRef = useInfiniteScrollObserver({
```

```
    hasNextPage: true,
    isFetchingNextPage: false,
    fetchNextPage: () => console.log('Loading more...'),
    // Adjust behavior based on scroll direction
    rootMargin: scrollPosition.direction === 'down' ? '300px' : '100px'
  });

  return (
    <div ref={containerRef} className="scroll-container">
      {/* Content */}
      <div ref={sentinelRef} className="load-more-sentinel" />
    </div>
  );
};
```

This implementation provides:

1. **Efficient Intersection Observer**: Modern, performant scroll detection
2. **Multiple Sentinel Elements**: Strategic placement for different purposes

3. **DOM Element Reuse**: Memory-efficient element pooling
4. **Scroll Position Tracking**: Direction-aware loading and optimization
5. **Performance Monitoring**: Built-in stats and debugging capabilities

The key insight is that modern infinite scroll combines **Intersection Observer** for efficient scroll detection, **sentinel/pivot elements** for precise triggering, and **DOM element pooling** for memory efficiency, creating a smooth, performant user experience even with thousands of items.

Data Models

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Post Schema ☐ Back to Top

```
Post {
  id: UUID
  author_id: UUID
  content: {
    text?: String
    media?: [MediaObject]
    links?: [LinkPreview]
    mentions?: [UserID]
```

```
    hashtags?: [String]
  }
  metadata: {
    created_at: DateTime
    updated_at: DateTime
    location?: GeoPoint
    privacy: 'public' | 'friends' | 'private'
    type: 'text' | 'image' | 'video' | 'link' | 'poll'
  }
  engagement: {
    likes_count: Integer
    comments_count: Integer
    shares_count: Integer
    views_count: Integer
    engagement_rate: Float
  }
  ranking_signals: {
    relevance_score: Float
    quality_score: Float
    freshness_score: Float
    virality_score: Float
  }
}
```

Feed Item Schema □ Back to Top

```
FeedItem {
  id: UUID
  post_id: UUID
  user_id: UUID
  score: Float
  position: Integer
  timestamp: DateTime
  reason: 'following' | 'trending' | 'suggested' | 'sponsored'
  metadata: {
    shown_at?: DateTime
    clicked_at?: DateTime
    engagement?: Object
    a_b_test_variant?: String
  }
}
```

API Design

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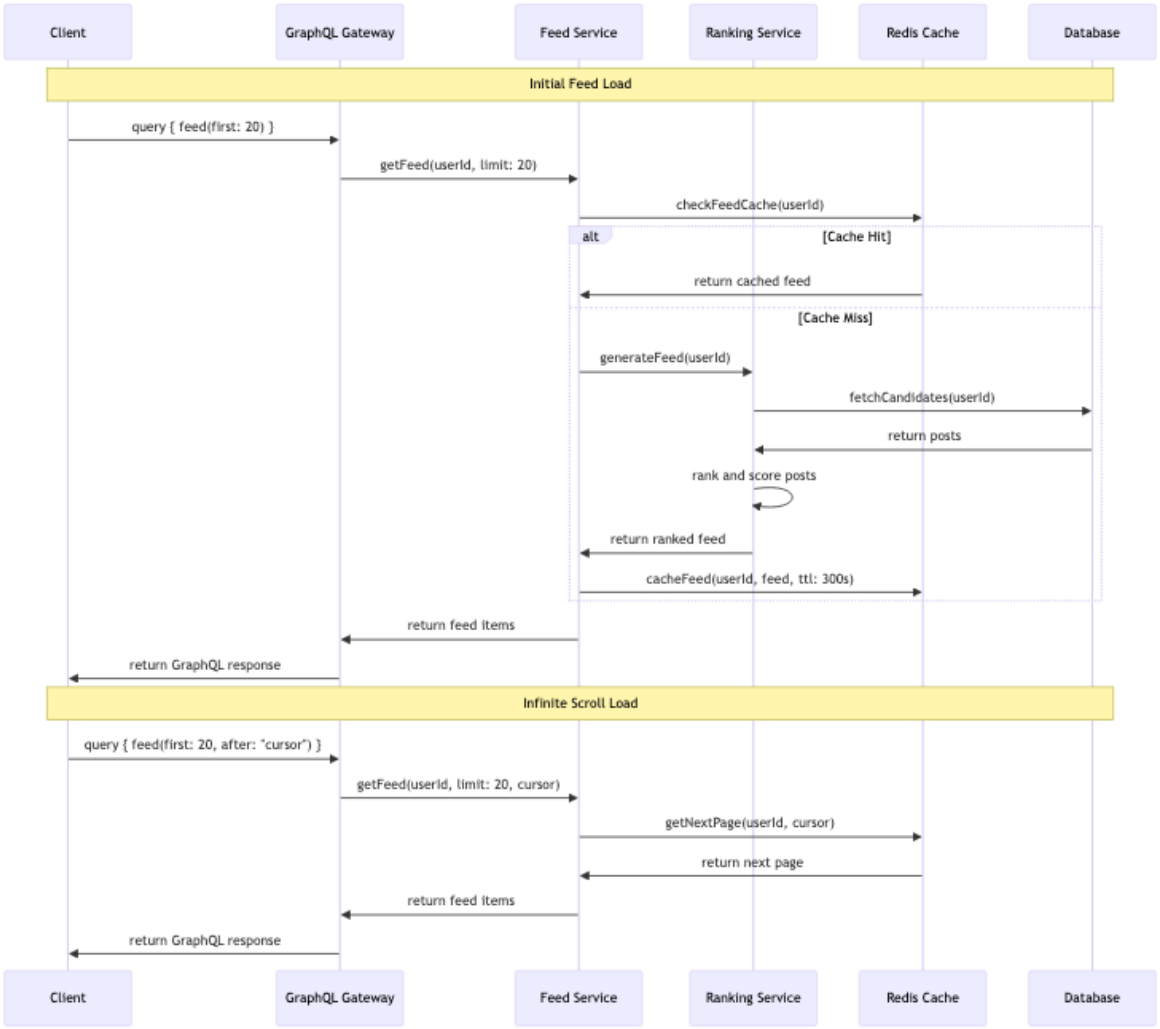
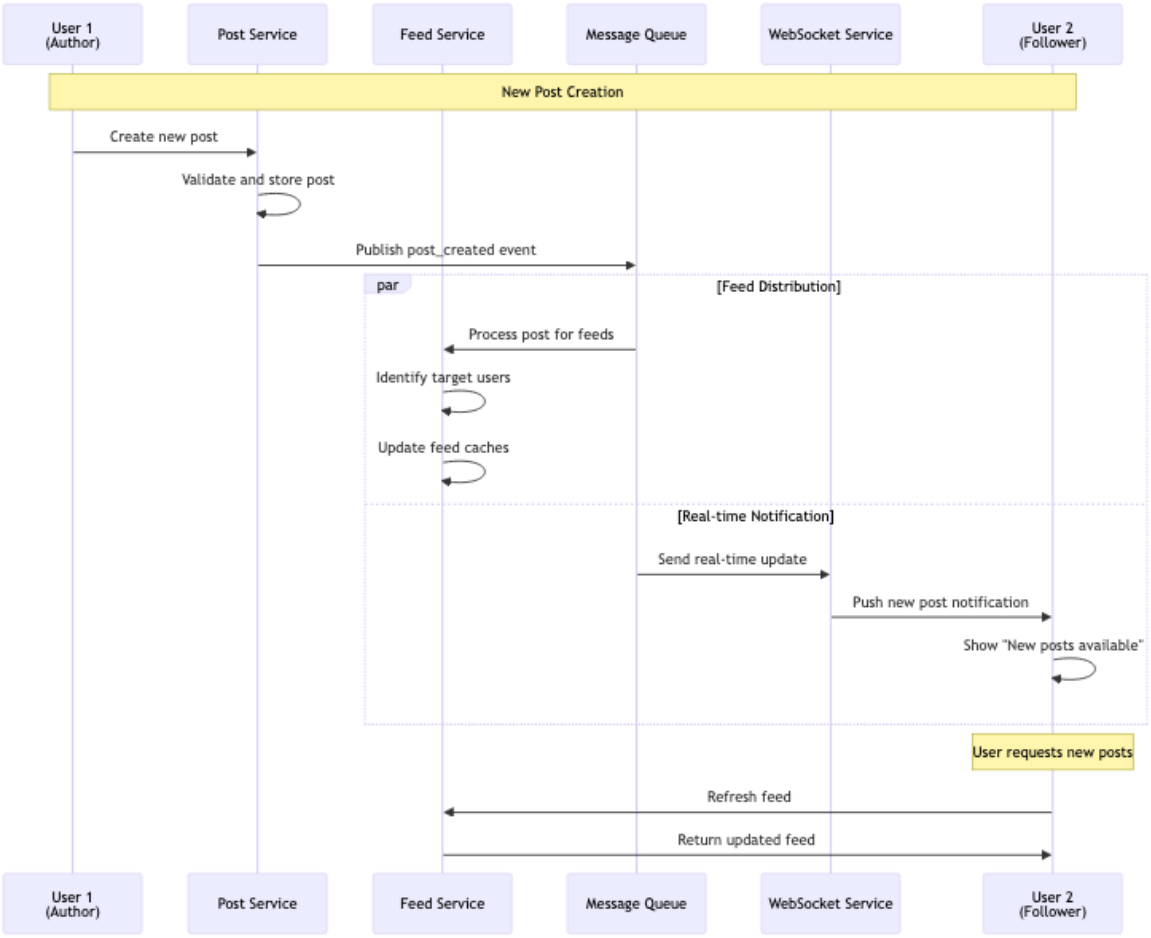
GraphQL Feed API □ Back to Top



Real-time Feed Updates □ Back to Top



Performance and Scalability

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Feed Caching Strategy

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Multi-Level Caching Architecture

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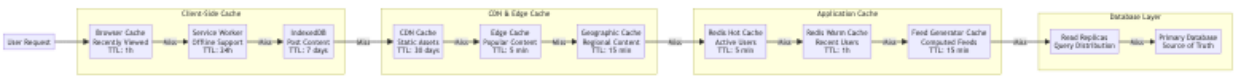

Database Scaling Strategy

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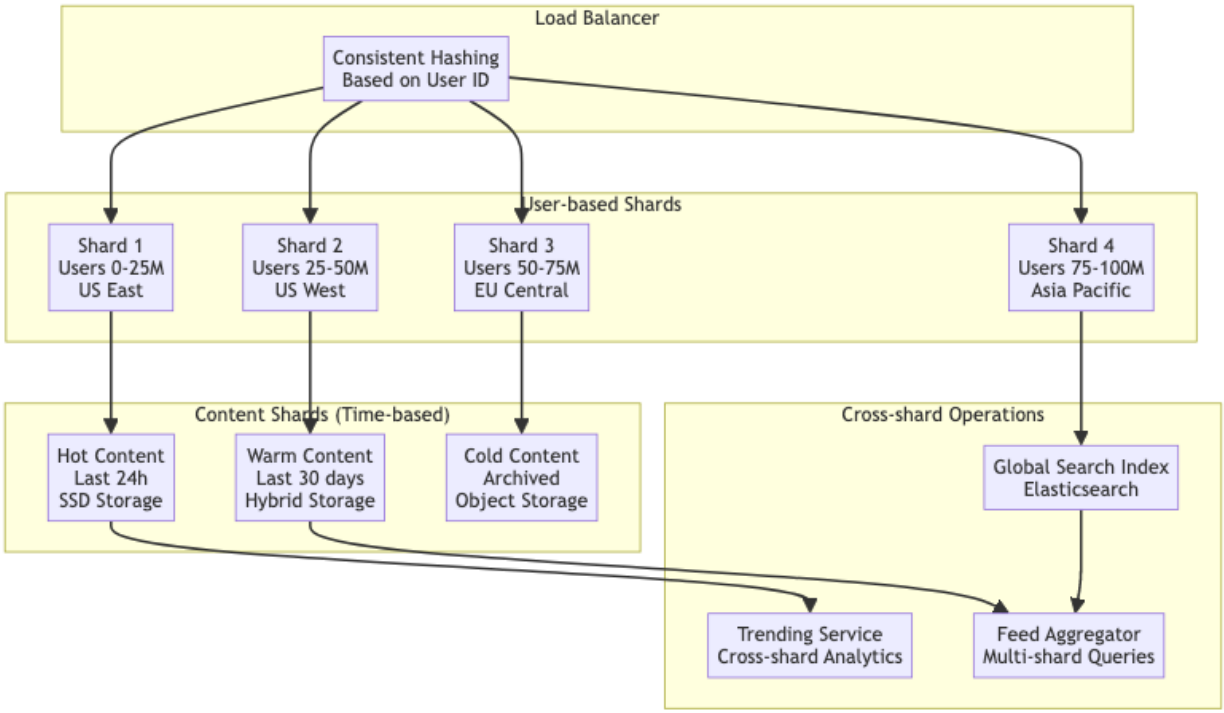
Horizontal Partitioning Back to Top



Content Delivery Optimization

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Progressive Loading Strategy Back to Top

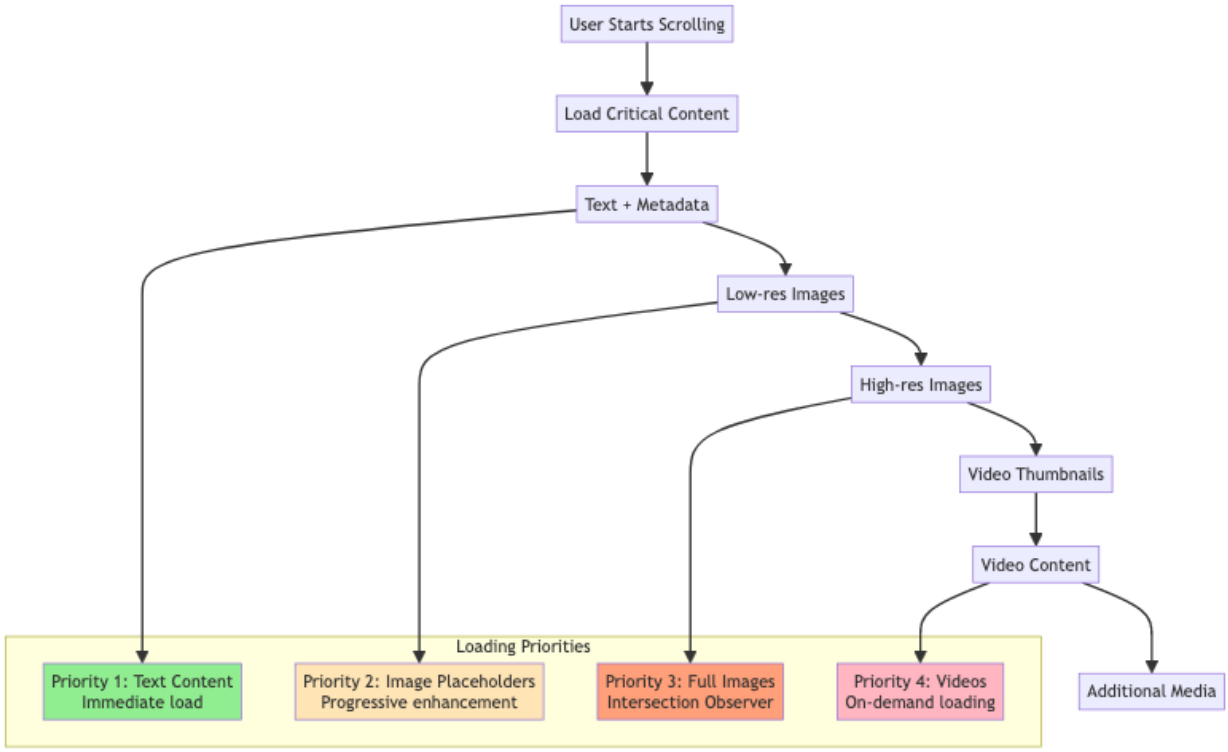
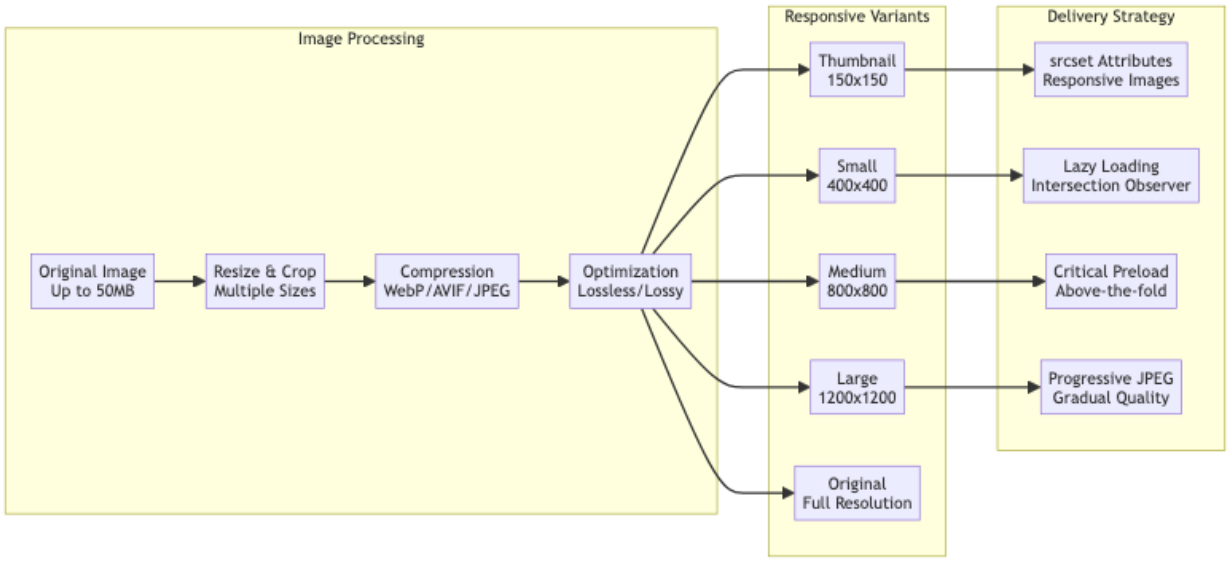


Image Optimization Pipeline Back to Top



Security and Privacy

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Content Security Framework

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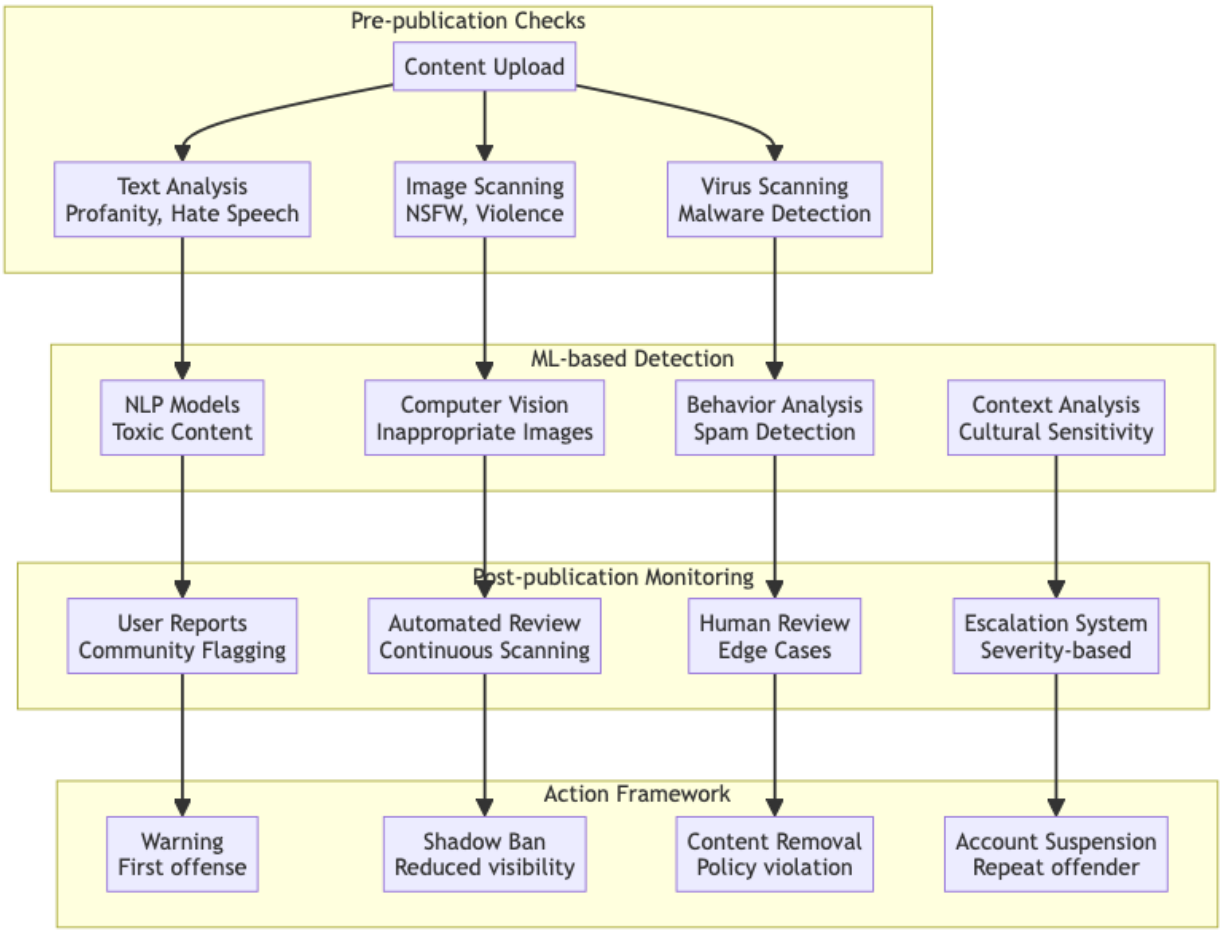
Content Moderation Pipeline □ Back to Top



Privacy Protection Strategy

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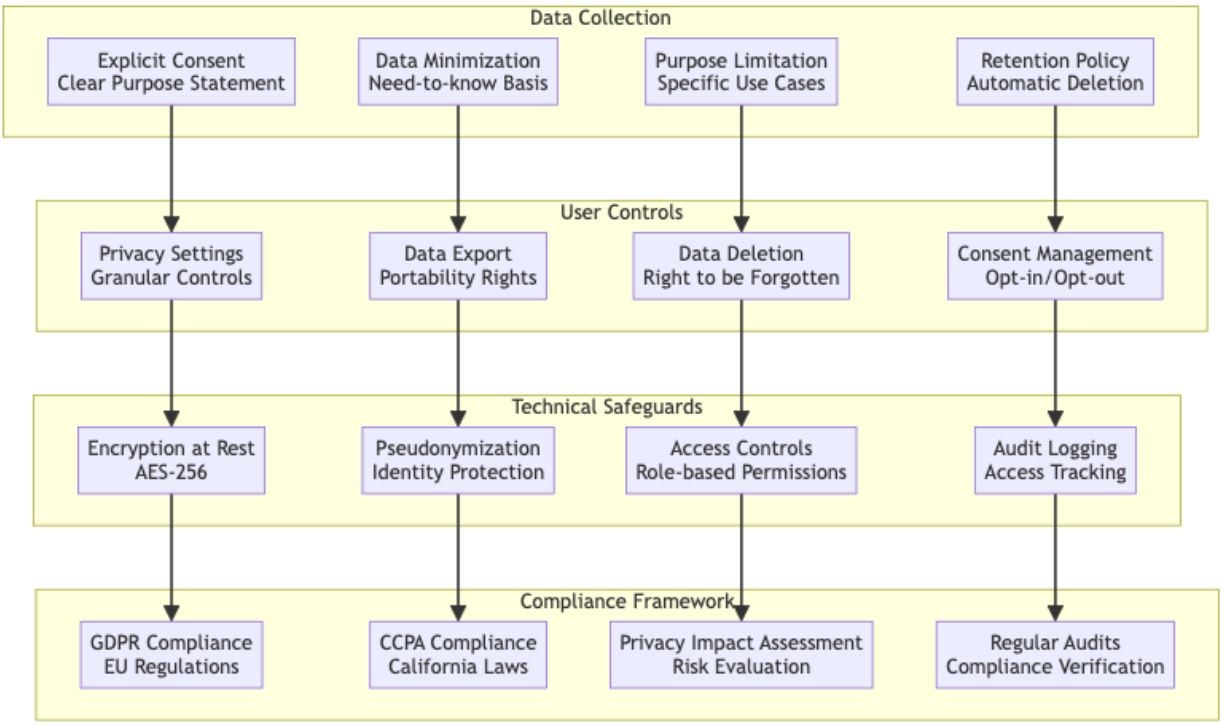
Data Privacy Controls □ Back to Top



Testing, Monitoring, and Maintainability

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Performance Testing Strategy

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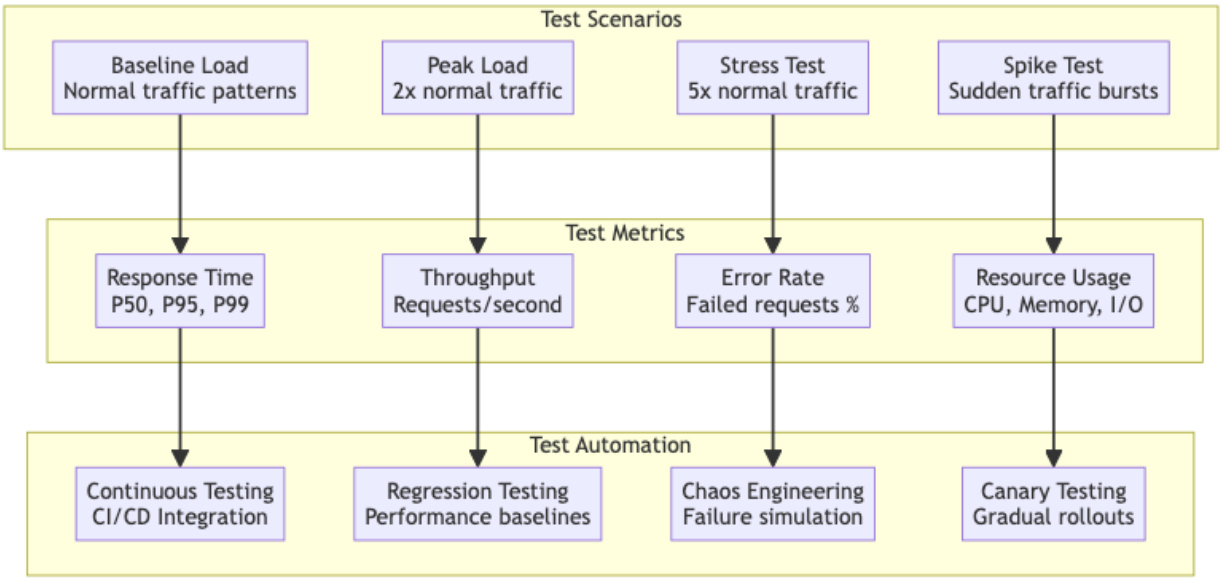
Load Testing Framework ☐ Back to Top



Real-time Monitoring Dashboard

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Key Performance Indicators Back to Top

Trade-offs, Deep Dives, and Extensions

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Infinite Scroll vs Pagination Trade-offs

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Aspect	Infinite Scroll	Traditional Pagination
User Engagement	Higher (seamless flow)	Lower (interruptions)
Performance	Complex (memory management)	Simple (fixed page size)
SEO	Challenging (dynamic content)	Excellent (static URLs)
Accessibility	Requires extra work	Native support
Back Button	Complex state management	Natural navigation
Deep Linking	Difficult implementation	Built-in support
Mobile Experience	Optimal for touch devices	Less intuitive

Feed Algorithm Trade-offs

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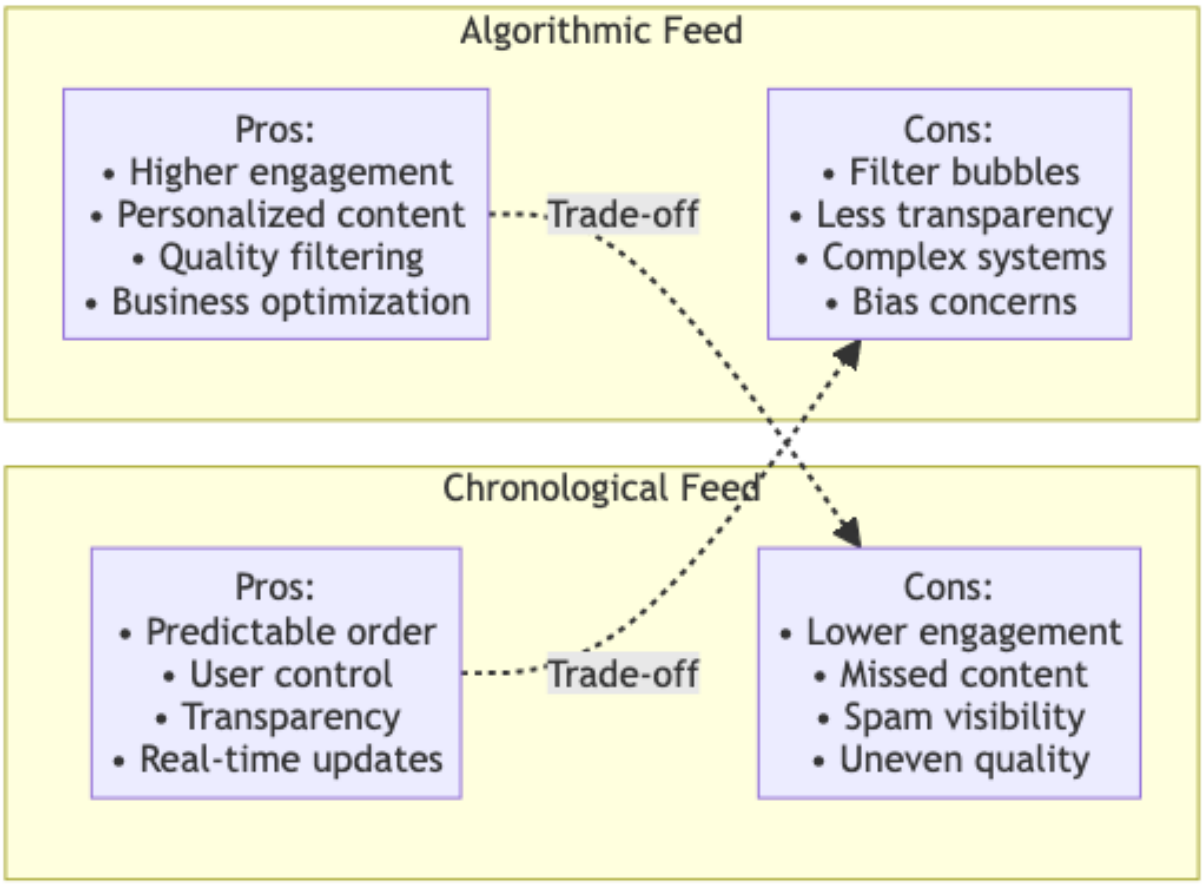
Chronological vs Algorithmic Feed □ Back to Top



Advanced Optimization Strategies

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Edge Computing for Feed Generation

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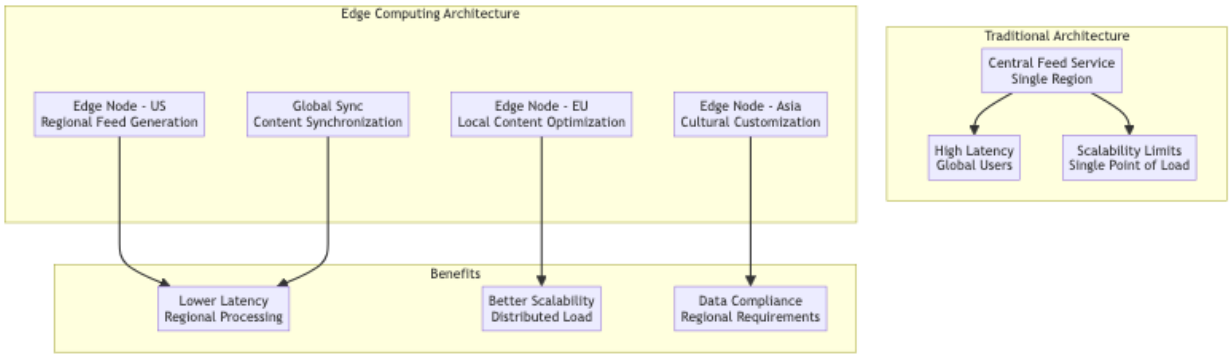
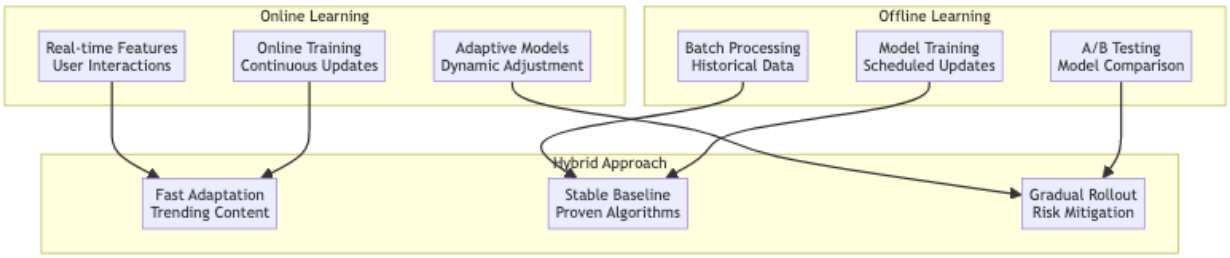


Machine Learning Pipeline Optimization ☐ Back to Top



Future Extensions

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Next-Generation Feed Features ☐ Back to Top

1. **Immersive Content**:
   - AR/VR feed experiences
   - 3D content rendering
   - Spatial computing integration
   - Gesture-based navigation
2. **AI-Enhanced Experience**:
   - Conversational feed interaction
   - Automated content summarization
   - Smart content categorization
   - Predictive content generation
3. **Advanced Personalization**:
   - Emotional state recognition
   - Context-aware content
   - Multi-modal preferences
   - Cross-platform behavior analysis
4. **Social Commerce Integration**:
   - Native shopping experiences
   - Social proof mechanisms
   - Influencer commerce tools
   - Virtual try-on features

This comprehensive design provides a robust foundation for building a high-performance, scalable infinite scrolling newsfeed system that can handle millions of users while delivering personalized, engaging content experiences.

TypeScript Interfaces & Component Props

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Core Data Interfaces

```typescript
interface FeedPost {
  id: string;
  authorId: string;
  content: PostContent;
  engagement: EngagementMetrics;
  timestamp: Date;
  visibility: 'public' | 'friends' | 'private';
  rankingScore: number;
  type: 'text' | 'image' | 'video' | 'link' | 'poll';
}

interface PostContent {
  text?: string;
  media?: MediaItem[];
  link?: LinkPreview;
  poll?: PollData;
  location?: GeoLocation;
  mentions?: string[];
  hashtags?: string[];
}

interface EngagementMetrics {
  likes: number;
  comments: number;
  shares: number;
  views: number;
  engagementRate: number;
  recentActivity: number;
}

interface FeedItem {
  id: string;
  post: FeedPost;
  author: UserProfile;
  userInteraction?: UserInteraction;
  rankingReason: 'following' | 'trending' | 'recommended' | 'sponsored';
  insertedAt: Date;
}
```

```typescript
interface UserProfile {
  id: string;
  username: string;
  displayName: string;
  avatarUrl?: string;
  isVerified: boolean;
  followerCount: number;
}
```

Component Props Interfaces

```typescript
interface InfiniteFeedProps {
  userId: string;
  feedType: 'home' | 'trending' | 'following' | 'discover';
  onPostInteraction: (postId: string, action: string) => void;
  onLoadMore: () => void;
  refreshTrigger?: number;
  enableVirtualization?: boolean;
  itemHeight?: number;
}

interface FeedItemProps {
  feedItem: FeedItem;
  onLike: (postId: string) => void;
  onComment: (postId: string) => void;
  onShare: (postId: string) => void;
  onUserClick: (userId: string) => void;
  showEngagement?: boolean;
  density: 'compact' | 'comfortable' | 'spacious';
}

interface PostComposerProps {
  onPostCreate: (content: PostContent) => void;
  onDraftSave: (draft: PostDraft) => void;
  characterLimit?: number;
  allowedMediaTypes?: string[];
  enablePolls?: boolean;
  enableLocation?: boolean;
}

interface FeedControlsProps {
  currentFilter: FeedFilter;
  onFilterChange: (filter: FeedFilter) => void;
  onRefresh: () => void;
```

```
  onSort: (sortBy: SortOption) => void;
  unreadCount?: number;
  isLoading?: boolean;
}
```

API Reference

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Feed Management

- `GET /api/feed` - Get personalized feed with infinite scroll pagination
- `GET /api/feed/trending` - Get trending posts with viral content detection
- `GET /api/feed/following` - Get chronological feed from followed users only
- `POST /api/feed/refresh` - Trigger feed refresh with new content check
- `GET /api/feed/discover` - Get discovery feed with recommended content

Post Operations

- `POST /api/posts` - Create new post with media upload and processing
- `GET /api/posts/:id` - Get specific post with full engagement data
- `PUT /api/posts/:id` - Edit post content (within edit time window)
- `DELETE /api/posts/:id` - Delete post and remove from all feeds
- `POST /api/posts/:id/boost` - Boost post visibility in algorithm

Engagement & Interactions

- `POST /api/posts/:id/like` - Like or unlike post with engagement tracking
- `POST /api/posts/:id/comments` - Add comment with mention and hashtag support
- `GET /api/posts/:id/comments` - Get paginated comments with nested replies
- `POST /api/posts/:id/share` - Share post with optional commentary
- `POST /api/posts/:id/save` - Save post to user's saved collection

Content Discovery

- `GET /api/explore/hashtags` - Get trending hashtags with usage metrics
- `GET /api/explore/topics` - Get trending topics and categories
- `GET /api/explore/users` - Get suggested users to follow
- `GET /api/search/posts` - Search posts with full-text and filter support
- `GET /api/recommendations` - Get ML-powered content recommendations

Real-time Updates

- `WS /api/feed/connect` - Establish WebSocket for real-time feed updates
- `WS FEED_UPDATE` - Receive new posts and engagement updates
- `WS POST_INTERACTION` - Broadcast post interactions to interested users
- `WS TRENDING_UPDATE` - Get real-time trending content notifications
- `WS USER_ACTIVITY` - Receive follower activity and mentions

Analytics & Insights

- `POST /api/analytics/view` - Track post view for algorithm training
- `POST /api/analytics/engagement` - Record engagement events with context
- `GET /api/analytics/insights` - Get content performance insights
- `POST /api/analytics/feedback` - Submit content relevance feedback
- `GET /api/analytics/trends` - Get content trend analysis

Feed Customization

- `GET /api/feed/preferences` - Get user's feed algorithm preferences
- `PUT /api/feed/preferences` - Update feed ranking and filtering preferences
- `POST /api/feed/hide` - Hide specific posts or content types
- `GET /api/feed/filters` - Get active content filters and blocked users
- `POST /api/feed/report` - Report inappropriate content for moderation